US009273691B2

(12) **United States Patent**
Yamada et al.

(10) **Patent No.:** **US 9,273,691 B2**
(45) **Date of Patent:** **Mar. 1, 2016**

(54) **ROTOR AND MOTOR**

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(73) Assignee: **ASMO, Co., Ltd.**, Shizuoka-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 444 days.

(21) Appl. No.: **13/662,834**

(22) Filed: **Oct. 29, 2012**

(65) **Prior Publication Data**

US 2013/0121856 A1 May 16, 2013

(30) **Foreign Application Priority Data**

Oct. 31, 2011	(JP)	2011-239516
Oct. 31, 2011	(JP)	2011-239520
Oct. 31, 2011	(JP)	2011-239521
Oct. 31, 2011	(JP)	2011-239522
Oct. 31, 2011	(JP)	2011-239523
Mar. 1, 2012	(JP)	2011-045694
Aug. 20, 2012	(JP)	2012-181634
Aug. 20, 2012	(JP)	2012-181637
Aug. 20, 2012	(JP)	2012-181638

(51) **Int. Cl.**
H02K 1/27 (2006.01)
F04D 13/06 (2006.01)
H02K 1/30 (2006.01)

(52) **U.S. Cl.**
CPC ***F04D 13/06*** (2013.01); ***H02K 1/2706*** (2013.01); ***H02K 1/2713*** (2013.01); ***H02K 1/30*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,212,192 A 8/1940 Howell
2,802,959 A * 8/1957 Powers 310/156.66

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1913299 A 2/2007
EP 2157679 A1 2/2010

(Continued)

OTHER PUBLICATIONS

Notice of Allowance corresponding to U.S. Appl. No. 13/662,781, dated Jan. 22, 2015, 26 pages.

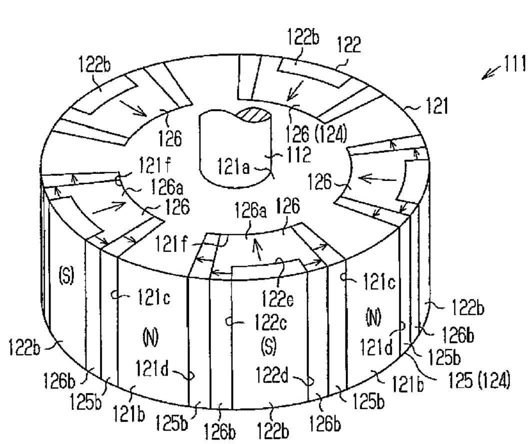
(Continued)

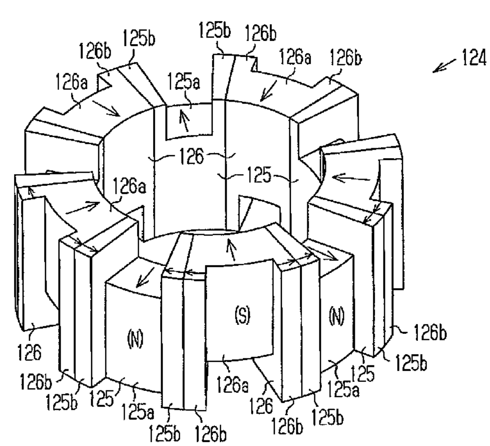
Primary Examiner — Tran Nguyen
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(57) **ABSTRACT**

A rotor includes a first rotor core, a second rotor core, a field magnet, and an auxiliary magnet. The first rotor core includes a first core base and a plurality of first hook-shaped poles. The second rotor core includes a second core base and a plurality of second hook-shaped poles. The first and second hook-shaped poles are alternately arranged in a circumferential direction of the rotor. The field magnet is arranged between the first and second core bases in an axial direction. The field magnet cause the first hook-shaped poles to function as first poles and the second hook-shaped poles to function as second poles. The auxiliary magnet includes at least two interpolar magnet portions, which are integrally formed. Each interpolar magnet portion is arranged in a void between the first hook-shaped pole and the second hook-shaped pole and magnetized in the circumferential direction.

17 Claims, 33 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

3,206,623	A *	9/1965	Snowdon	310/162
4,388,545	A	6/1983	Honsinger et al.	
4,633,113	A	12/1986	Patel	
4,882,515	A	11/1989	Radomski	
4,959,577	A	9/1990	Radomski	
5,132,581	A	7/1992	Kusase	
5,483,116	A *	1/1996	Kusase et al.	310/263
5,502,424	A *	3/1996	Kato et al.	335/284
5,543,676	A	8/1996	York et al.	
5,663,605	A	9/1997	Evans et al.	
5,747,913	A	5/1998	Amlee et al.	
5,780,953	A *	7/1998	Umeda et al.	310/263
5,903,084	A	5/1999	Asao et al.	
5,925,964	A *	7/1999	Kusase et al.	310/263
5,969,459	A	10/1999	Taniguchi et al.	
6,002,194	A *	12/1999	Asao	310/263
6,013,967	A	1/2000	Ragaly et al.	
6,013,968	A *	1/2000	Lechner et al.	310/263
6,037,695	A	3/2000	Kanazawa et al.	
6,104,118	A *	8/2000	Kanazawa et al.	310/263
6,157,111	A *	12/2000	Asao	310/263
6,201,335	B1	3/2001	Higashino et al.	
6,311,383	B1 *	11/2001	Umeda et al.	29/596
6,331,746	B1	12/2001	Fujitani et al.	
6,426,581	B1	7/2002	York et al.	
6,437,477	B1	8/2002	Krefta et al.	
6,455,978	B1	9/2002	Krefta et al.	
6,483,212	B1	11/2002	Mimura et al.	
6,515,390	B1	2/2003	Lopatinsky et al.	
6,538,358	B1	3/2003	Krefta et al.	
6,720,703	B1 *	4/2004	Braun et al.	310/263
6,853,111	B2 *	2/2005	Umeda et al.	310/263
7,569,968	B2	8/2009	Nakamura	
7,605,519	B2	10/2009	Morita et al.	
7,737,602	B2	6/2010	Harada	
7,750,529	B2	7/2010	Tajima et al.	
7,843,107	B2	11/2010	Inoue et al.	
7,893,594	B2	2/2011	Fujita et al.	
7,919,900	B2 *	4/2011	Kusase	310/263
7,969,057	B2 *	6/2011	Kusase et al.	310/181
7,994,684	B2	8/2011	Inoue et al.	
8,067,874	B2 *	11/2011	Kusase	310/263
8,624,459	B2	1/2014	Tokizawa	
2003/0102758	A1	6/2003	Kusase et al.	
2004/0205955	A1	10/2004	Kawai et al.	
2005/0184617	A1	8/2005	Fujita et al.	
2006/0202582	A1 *	9/2006	Umesaki et al.	310/162
2007/0029886	A1	2/2007	Shiga	
2007/0035198	A1	2/2007	Maeda et al.	
2007/0046139	A1	3/2007	Ishizuka	
2007/0236098	A1	10/2007	Kusase et al.	
2007/0241633	A1	10/2007	Kusase et al.	
2007/0267938	A1	11/2007	Nishimura	
2008/0007126	A1	1/2008	Popov et al.	
2008/0018190	A1	1/2008	Takahata et al.	
2008/0048516	A1 *	2/2008	Oowatari et al.	310/156.71
2008/0088199	A1	4/2008	Hamada	
2008/0211337	A1 *	9/2008	Lutz et al.	310/156.66
2008/0315714	A1	12/2008	Badey et al.	
2009/0218907	A1	9/2009	Kusase	
2010/0148612	A1	6/2010	Takemoto et al.	
2010/0226803	A1	9/2010	Tajima et al.	
2013/0057102	A1	3/2013	Yamada et al.	
2013/0069471	A1	3/2013	Kadiri et al.	
2013/0106208	A1	5/2013	Yamada et al.	
2013/0106229	A1	5/2013	Goto et al.	
2013/0106230	A1	5/2013	Morita et al.	
2013/0113323	A1	5/2013	Yamada et al.	
2013/0113329	A1	5/2013	Yokoyama et al.	
2013/0121856	A1	5/2013	Yamada et al.	
2013/0147288	A1	6/2013	Jack et al.	
2013/0270928	A1	10/2013	Nord	

FOREIGN PATENT DOCUMENTS

GB	987882	A	3/1965
JP	S52-74410	U	6/1977
JP	S56-12846	A	2/1981
JP	S6043059	A	3/1985
JP	S61199446	A	9/1986
JP	H01101166	U	7/1989
JP	H03-251067	A	11/1991
JP	5-43749	U	6/1993
JP	H05344667	A	12/1993
JP	H0670526	A	3/1994
JP	H08308190	A	11/1996
JP	9327139		12/1997
JP	H10201149	A	7/1998
JP	11-098787	A	4/1999
JP	H11-150902	A	6/1999
JP	H11206052	A	7/1999
JP	2000-209825	A	7/2000
JP	2000224830	A	8/2000
JP	2001-086715	A	3/2001
JP	2001178092	A	6/2001
JP	2002101625	A	4/2002
JP	2003032930	A	1/2003
JP	2003506005	A	2/2003
JP	2003339129	A	11/2003
JP	2004320887	A	11/2004
JP	2005110403	A	4/2005
JP	2006003251	A	1/2006
JP	2006230125	A	8/2006
JP	2007-228677	A	9/2007
JP	2007-282420	A	10/2007
JP	2007288864	A	11/2007
JP	2007330025	A	12/2007
JP	2007330095	A	12/2007
JP	2008131692	A	6/2008
JP	2008535453	A	8/2008
JP	2010-213455	A	9/2010
JP	2010226922	A	10/2010
JP	2010239818	A	10/2010
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JP	2011-019994	A	3/2011
JP	2011067057	A	3/2011
JP	2011097756	A	5/2011
JP	2011-120419	A	6/2011
JP	2012-115085	A	6/2012
WO	WO2007043161	A1	4/2007
WO	WO2012/067223	A1	5/2012

OTHER PUBLICATIONS

Notice of Allowance and Fee Due related to corresponding U.S. Appl. No. 13/662,762.

Office Action corresponding to U.S. Appl. No. 13/662,810, dated Feb. 24, 2015, 8 pages.

Office Action dated Apr. 21, 2015 corresponding to the Japanese Patent Application No. 2011-239512.

Office Action dated Apr. 21, 2015 corresponding to the Japanese Patent Application No. 2011-239513.

Office Action dated Apr. 14, 2015 corresponding to Japanese Patent Application No. 2011-241284.

Office Action dated Apr. 14, 2015 corresponding to Japanese Patent Application No. 2011-239518.

Office Action dated Apr. 14, 2015 corresponding to Japanese Patent Application No. 2011-239517.

Office Action dated Apr. 14, 2015 corresponding to Japanese Patent Application No. 2011-239511.

Office Action of Mar. 17, 2015 corresponding to the Japanese Patent Application No. 239514.

Office Action corresponding to the Japanese Patent Application No. 2011-239523.

Office Action dated Jun. 2, 2015 corresponding to Japanese Patent Application No. 2011-247668.

Office Action corresponding to JP 2011-241284, received on Sep. 29, 2015, three pages.

(56) **References Cited**

OTHER PUBLICATIONS

Translation of Office Action for the corresponding Japanese Application No. 2012-121183, received on Oct. 27, 2015, five pages.
Office Action for corresponding Chinese Application No. 2012-10440787.4, dated Dec. 8, 2015, 2015, five pages.
Office Action for corresponding Chinese Application No. 2012-10440788.9, dated Dec. 28, 2015, five pages.
Office Action for Japanese Application No. 2015-075072, dated Jan. 5, 2016, two pages.

* cited by examiner

Fig.1

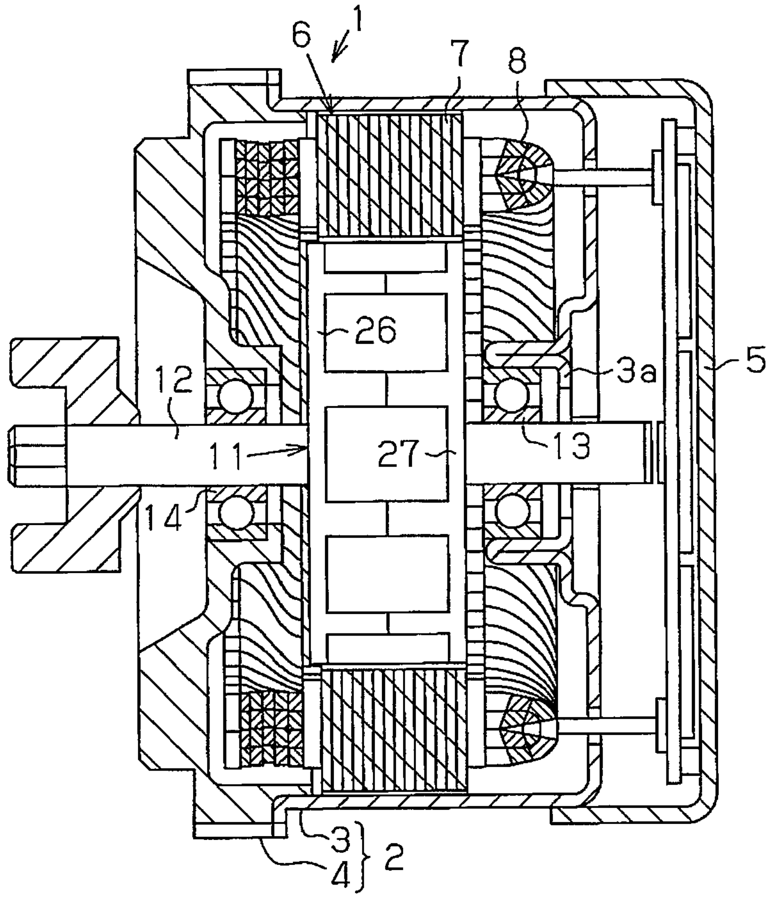

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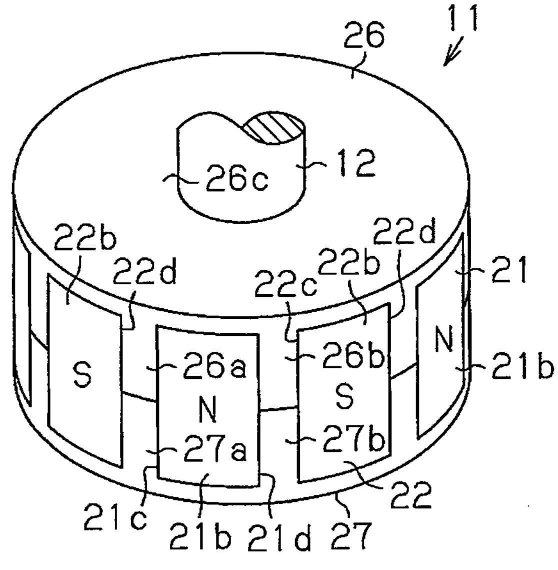
Fig.2



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21c
21b
21d
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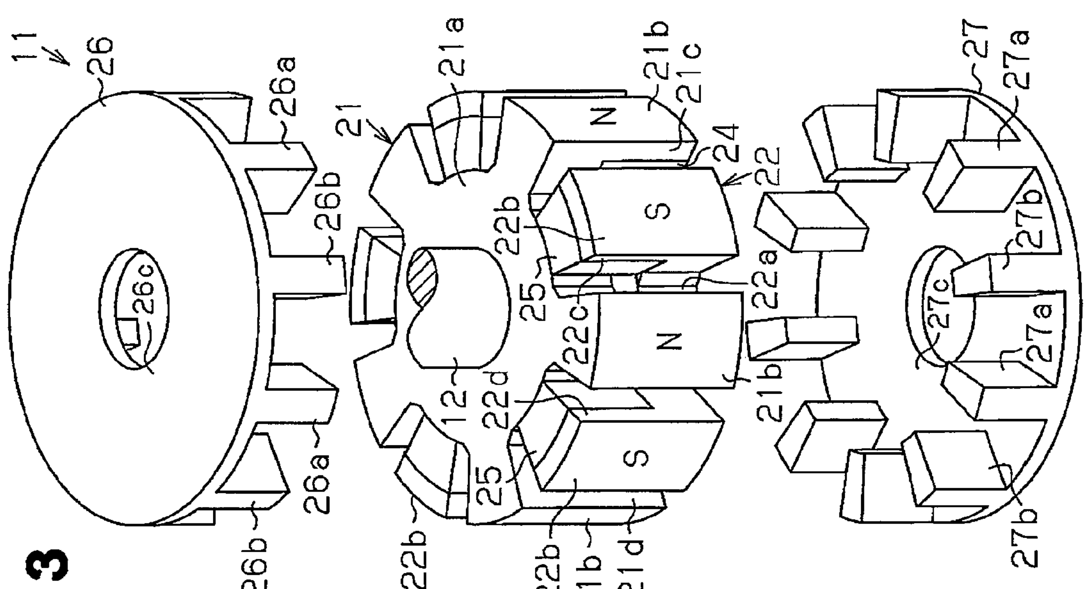

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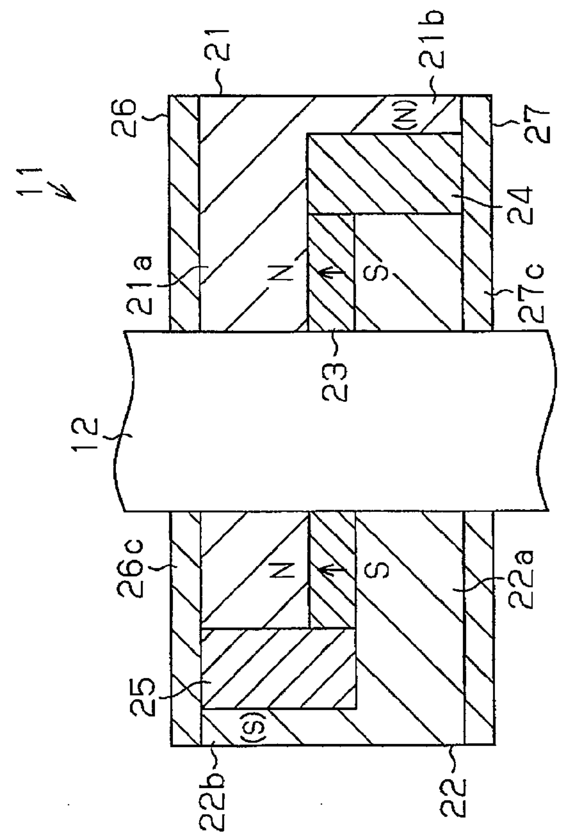
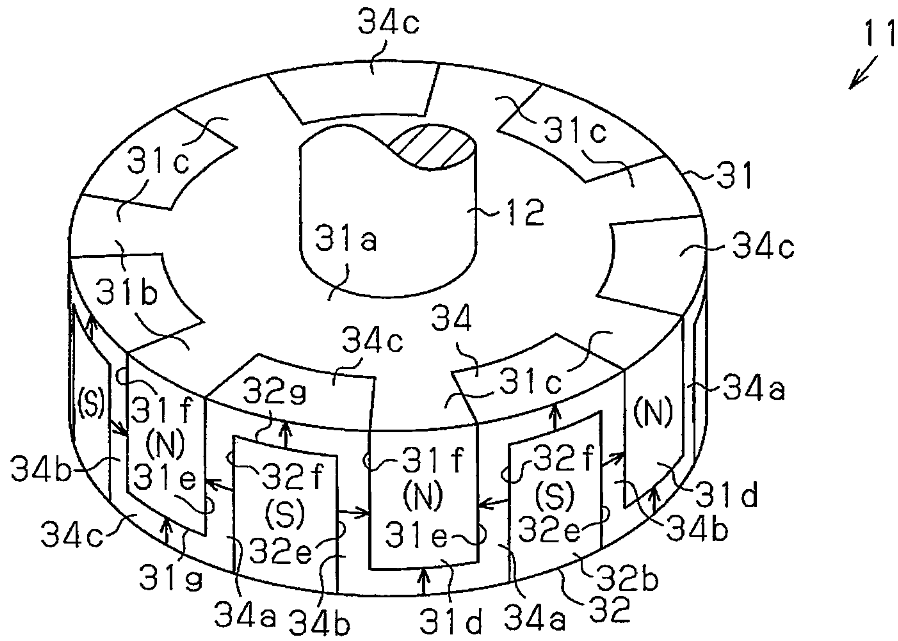


Fig. 4

Fig.5



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32e
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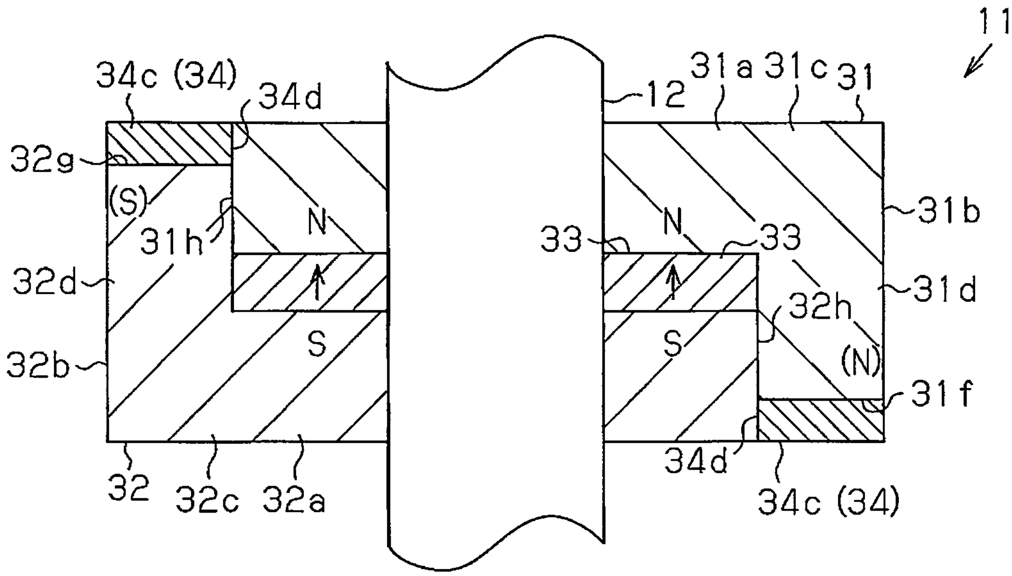
Fig.6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(N)
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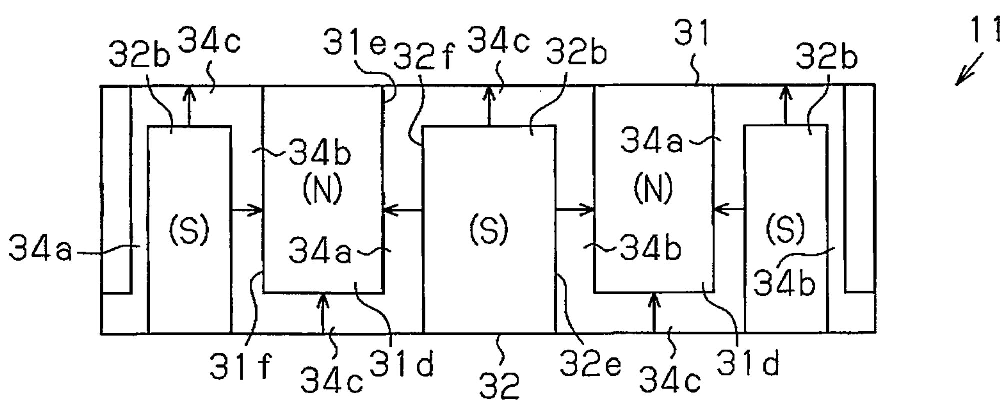
34d
34c (34)
32
32c
32a

Fig.7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(N)
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(S)
(S)
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34b
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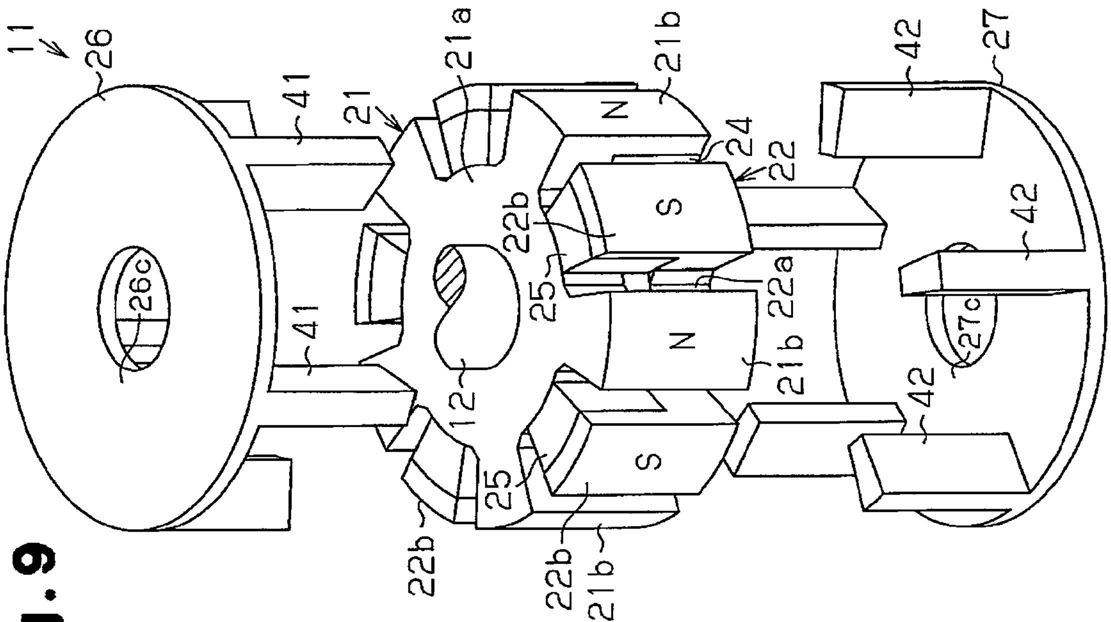
34c
31d
32
32e
34c
31d

Fig.9



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27c
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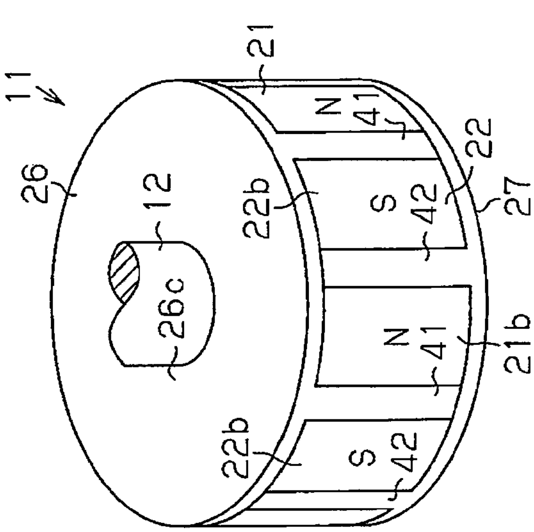
Fig.8



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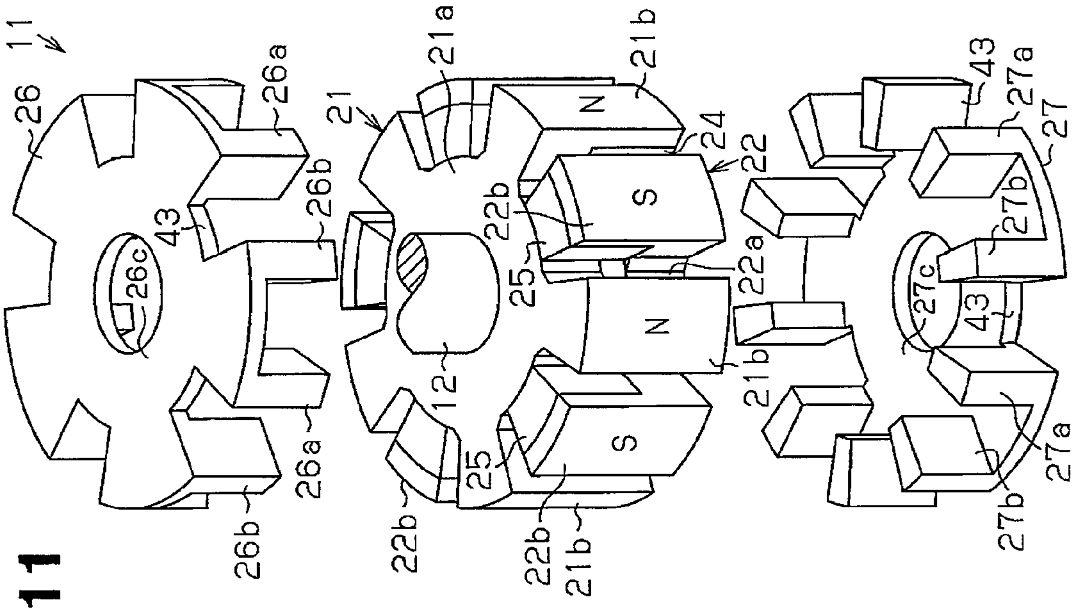
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27b

Fig.11

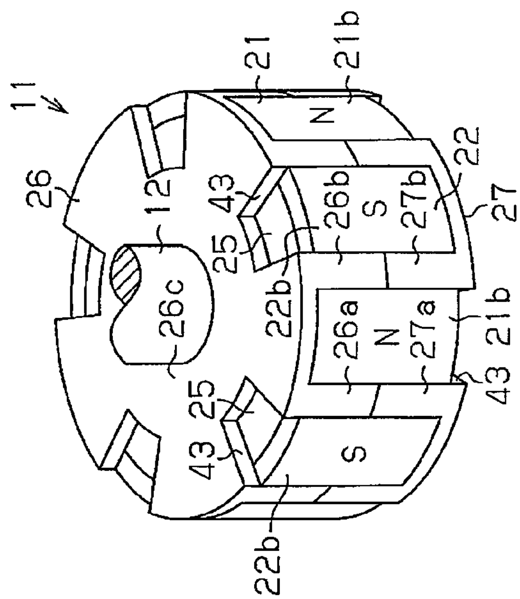
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Fig.10

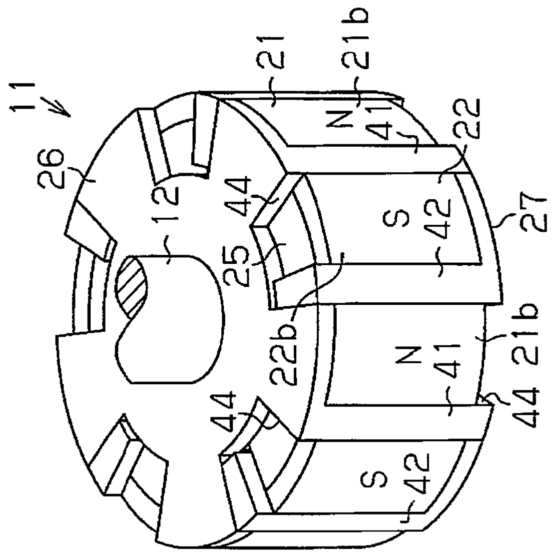
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Fig.13

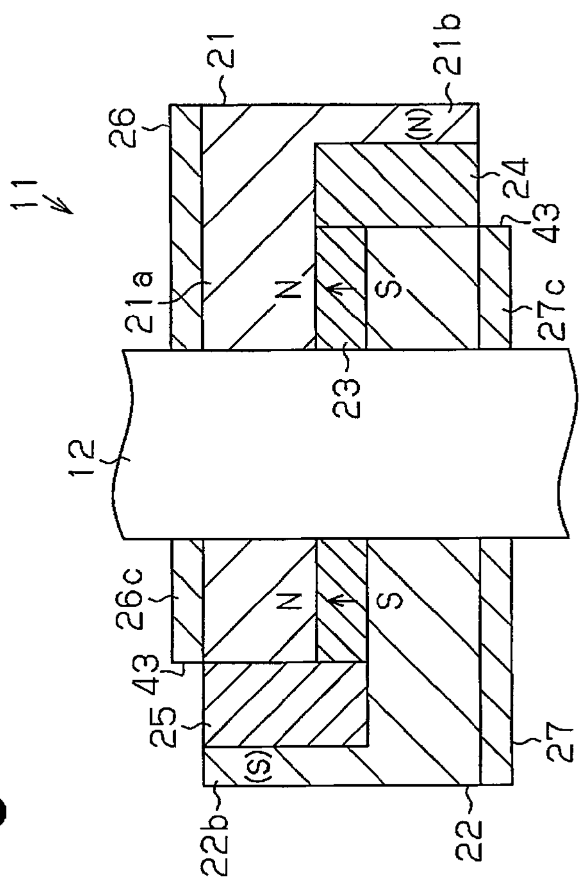
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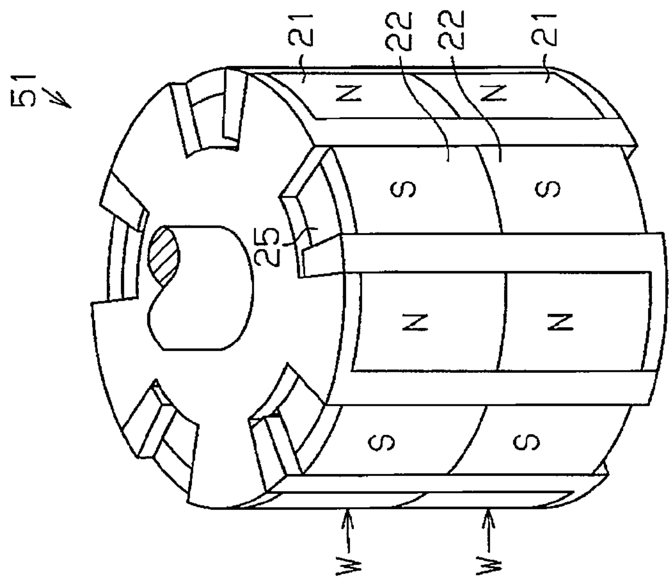
Fig.12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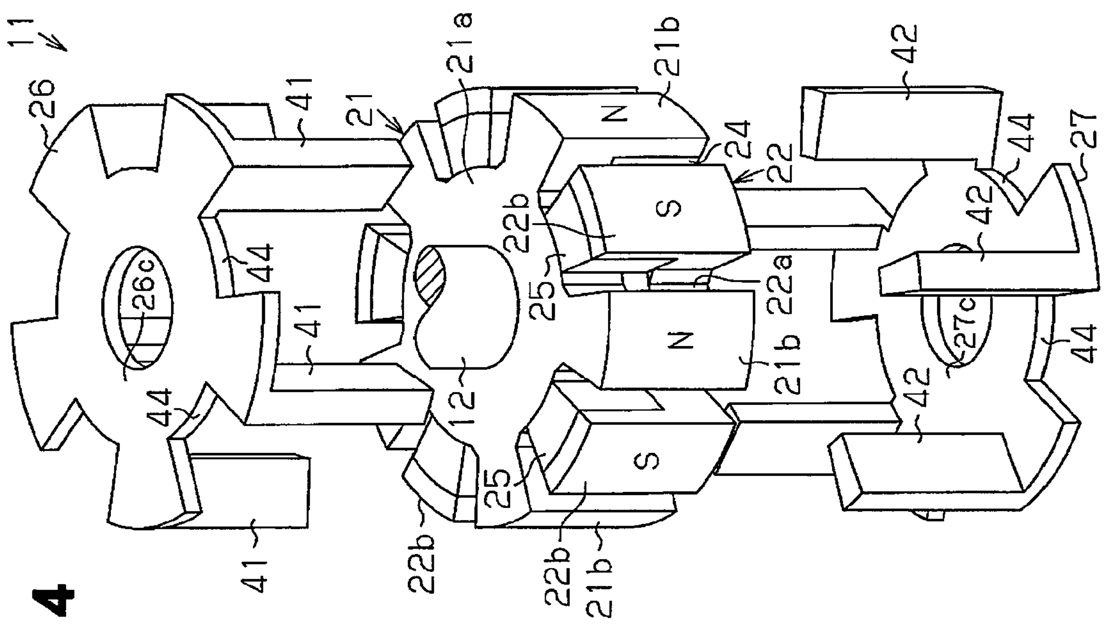
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27c
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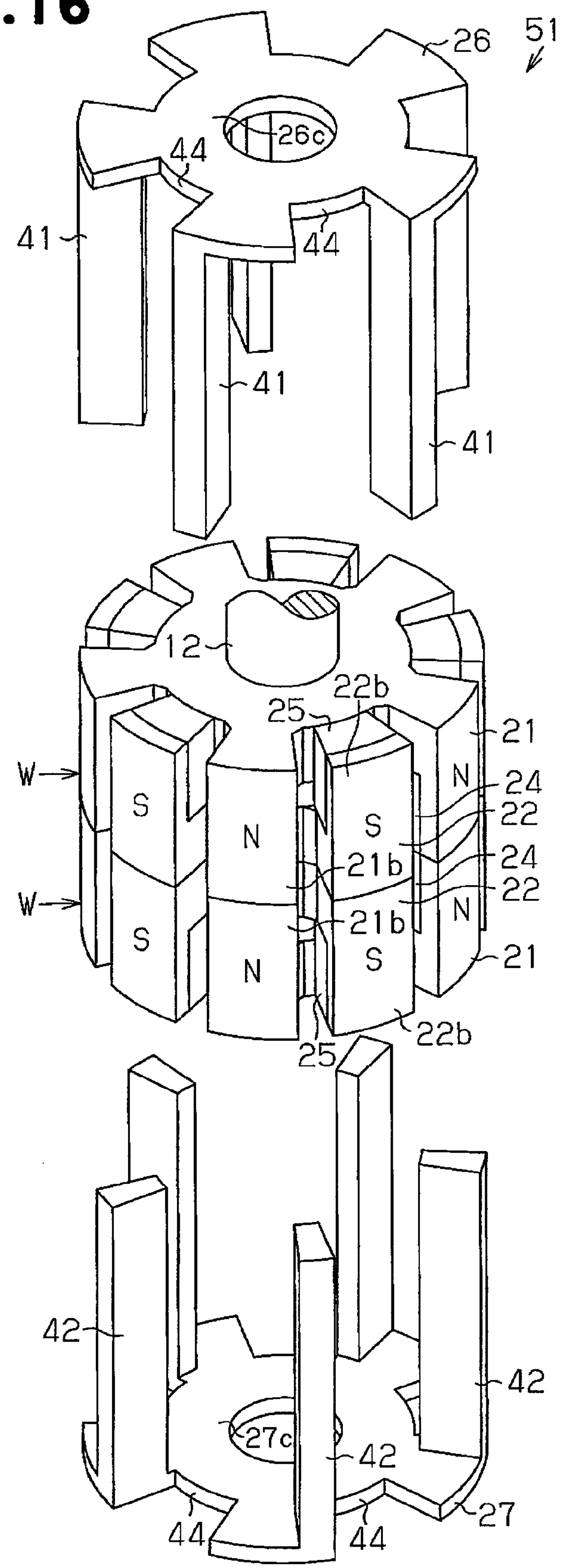
Fig.14

Fig.16



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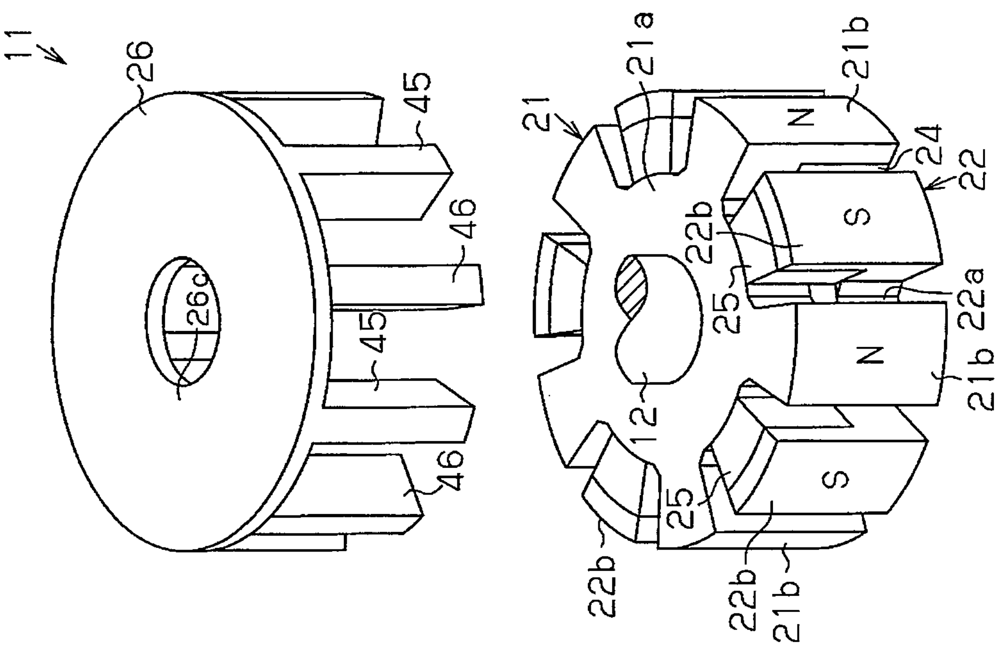
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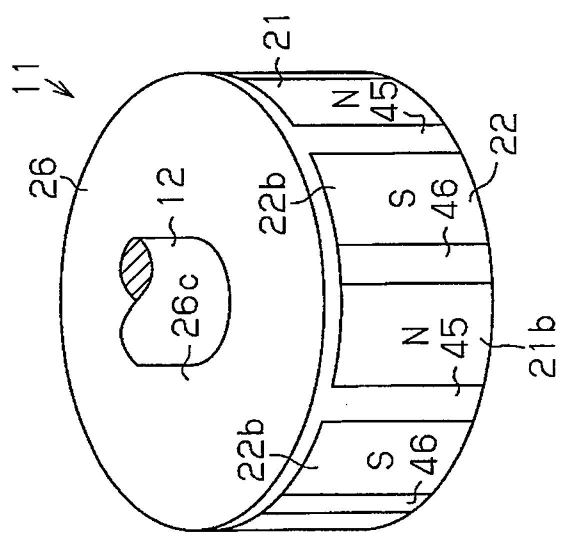
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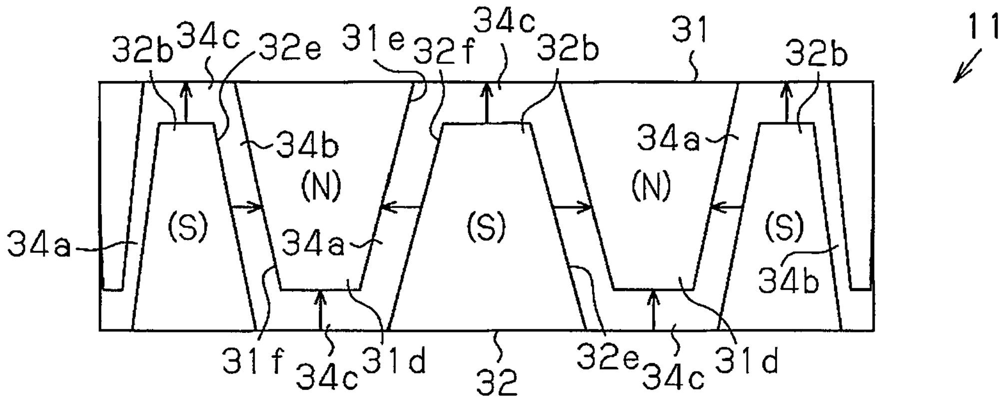
Fig.17

Fig.19



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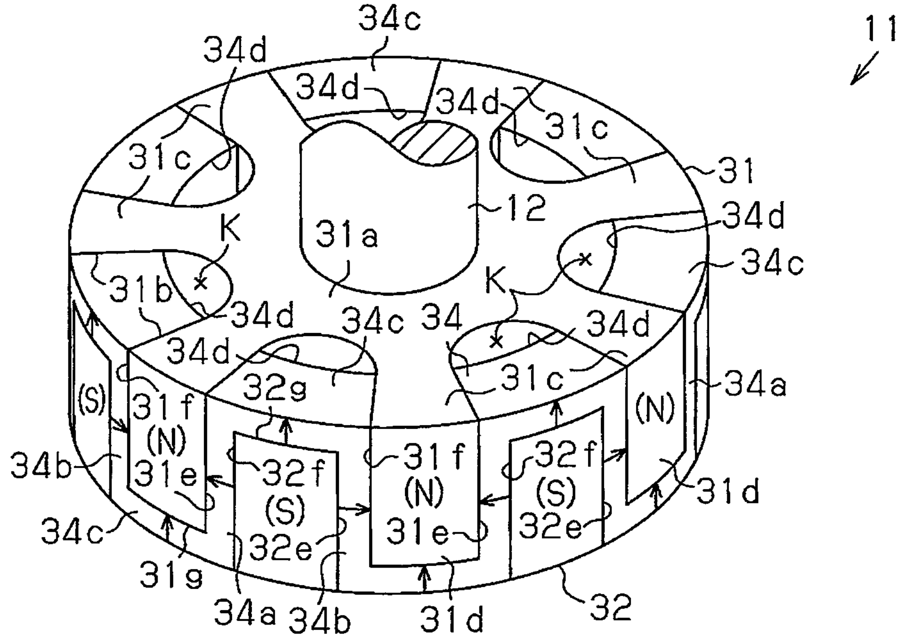
32e
31d

Fig.20



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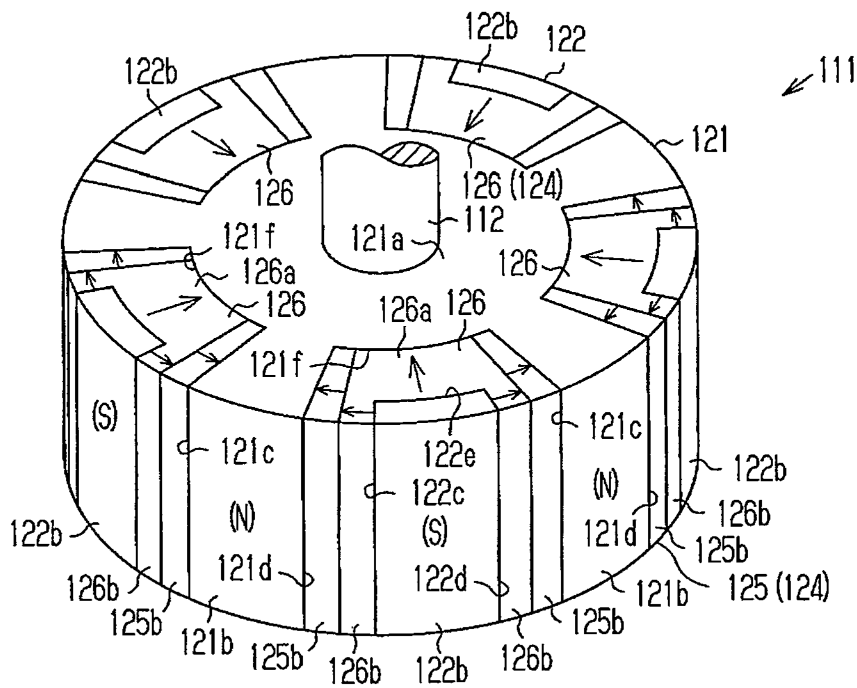

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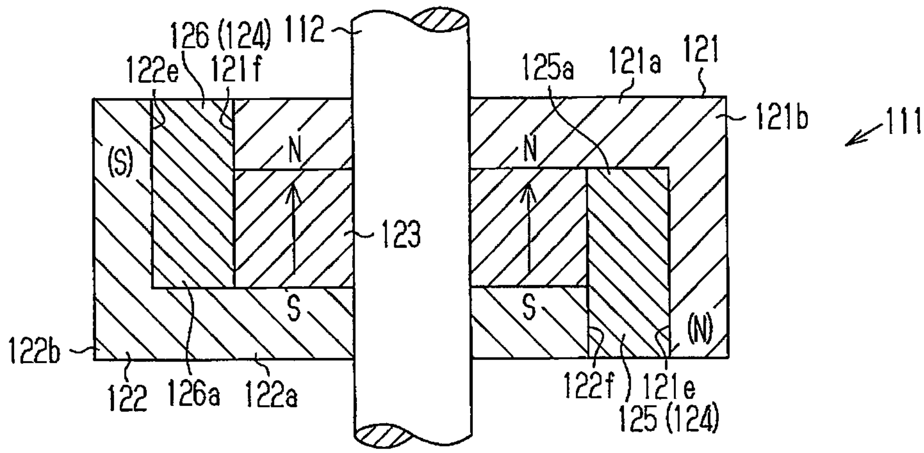
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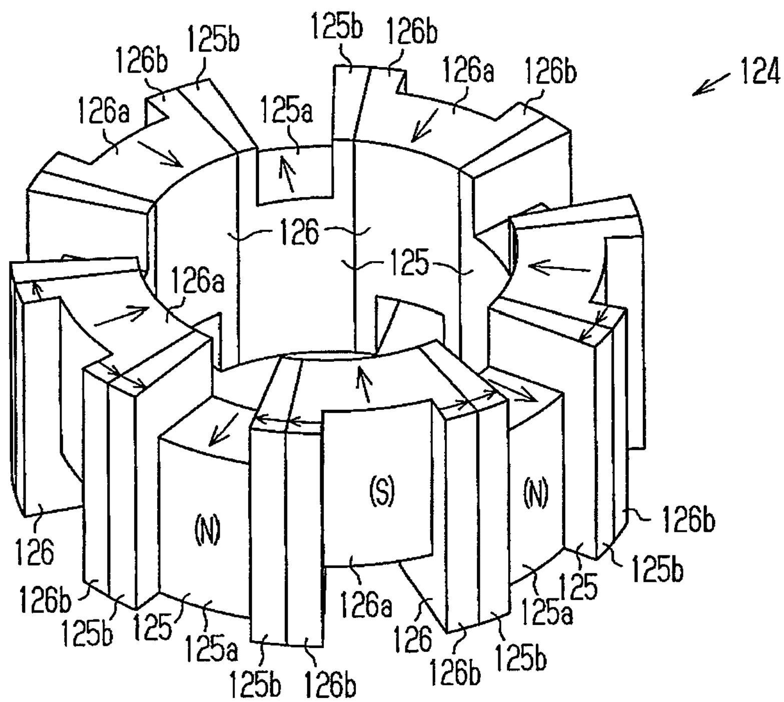
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125a
126
125
126a
(S)
(N)
(N)
126b
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125b
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126b
125b
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125a
126a
125a
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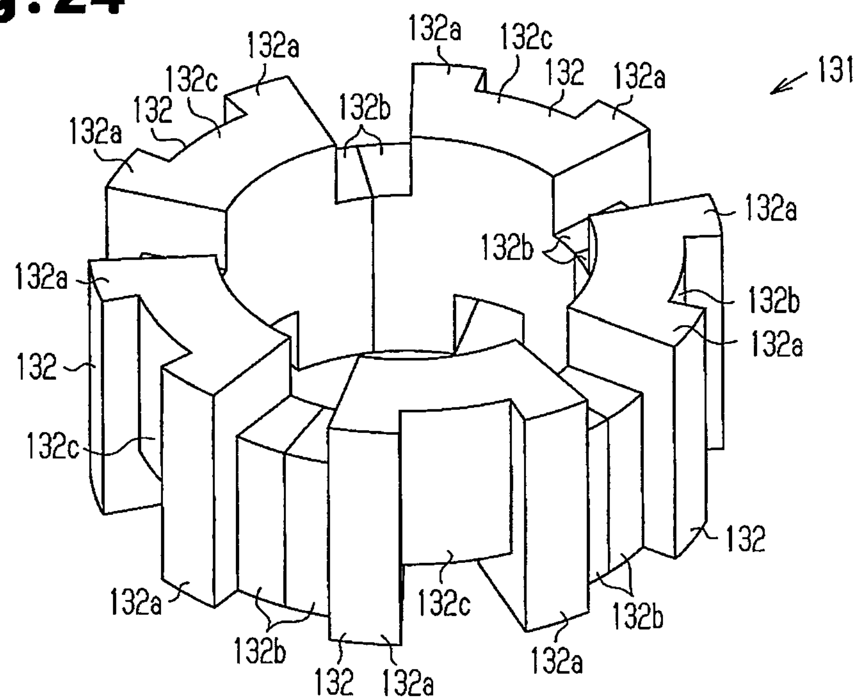
125b
126b
126b
125b

Fig.24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132b
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132c
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132c
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132a
132b
132
132a
132c
132a
132b

Fig.25

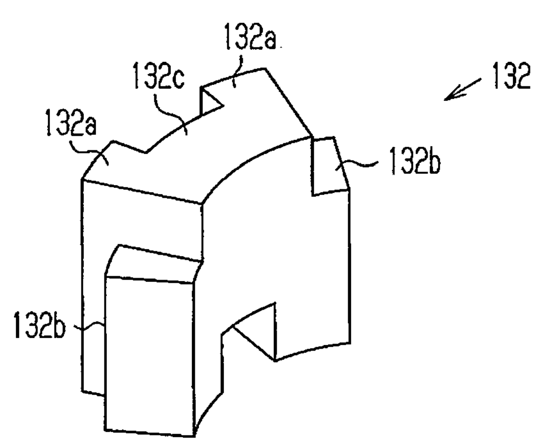
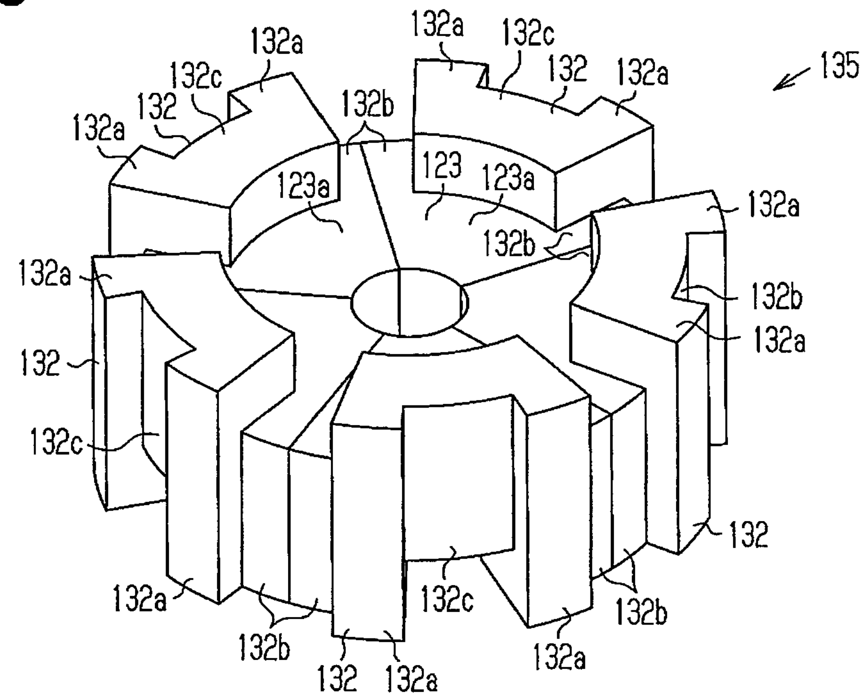

132
132a
132c
132a
132b
132b

Fig.26



132a
132c
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132a
135
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132
132a
132b
123
123a
123a
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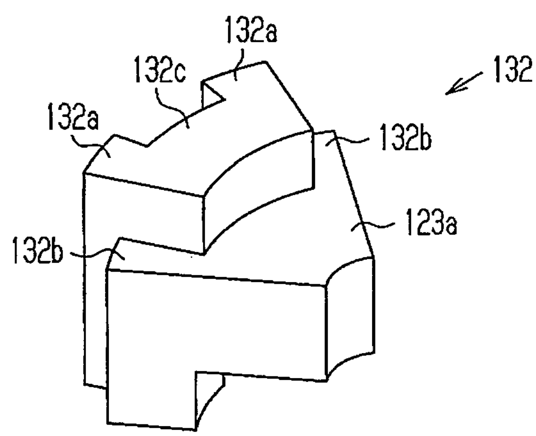
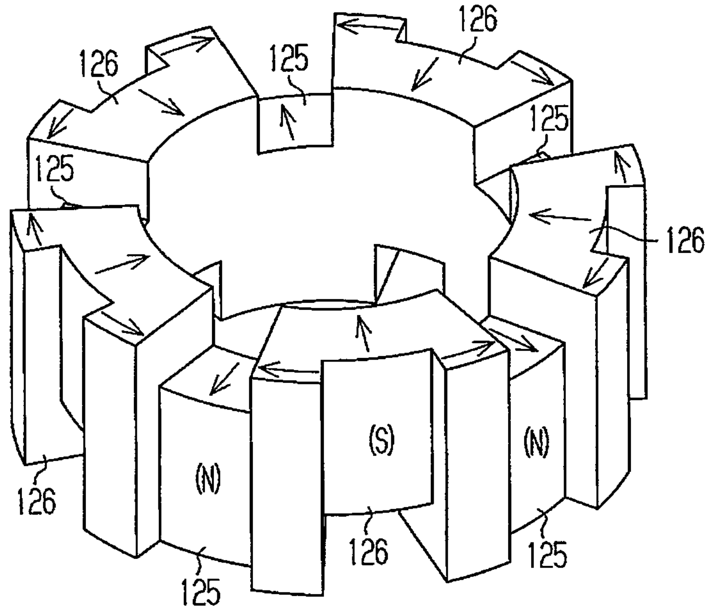
132a
132b
132
132a
132c
132
132a
132c
132b
132
132a
132a
132b

Fig.27



132a
132c
132a
132
132b
123a
132b

Fig.28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125
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125
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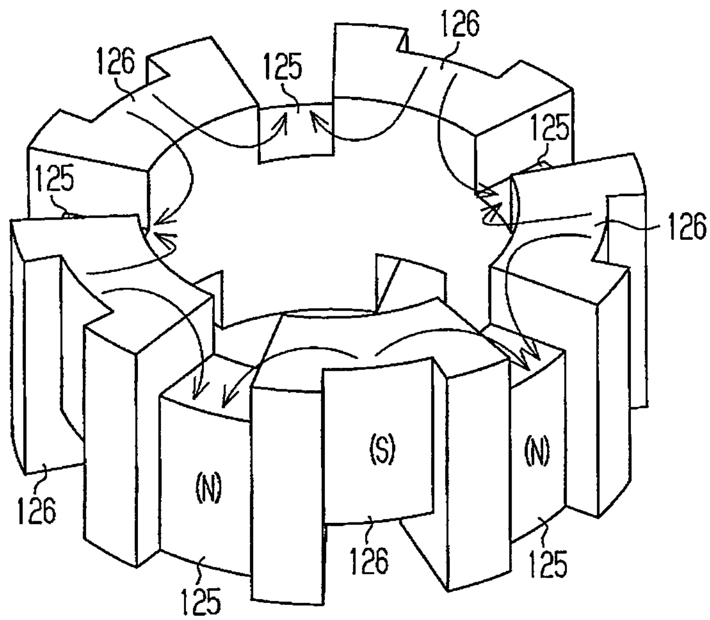
126
(N)
(S)
(N)
126
125
125

Fig.29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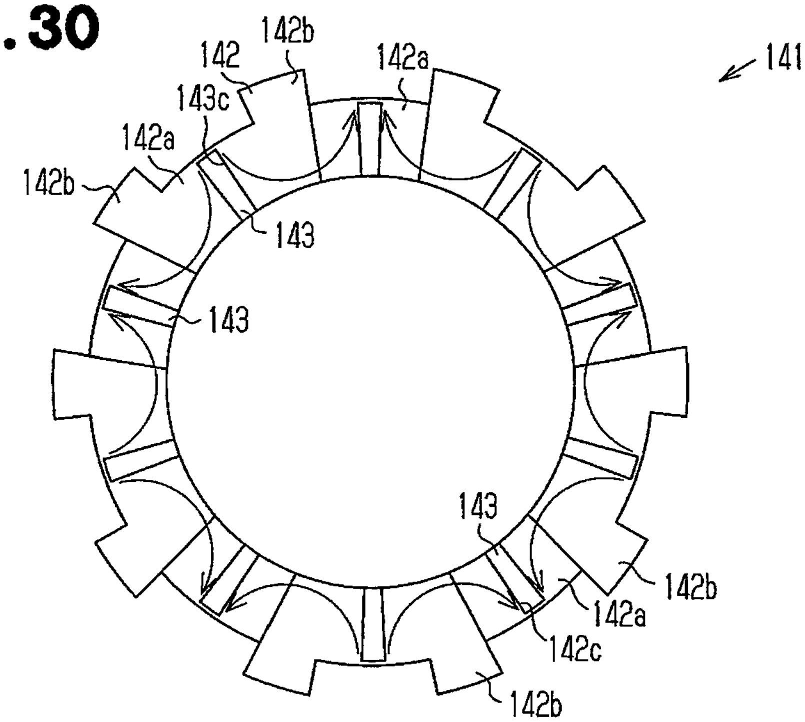
126
126
(N)
(S)
(N)
126
125
125

Fig.30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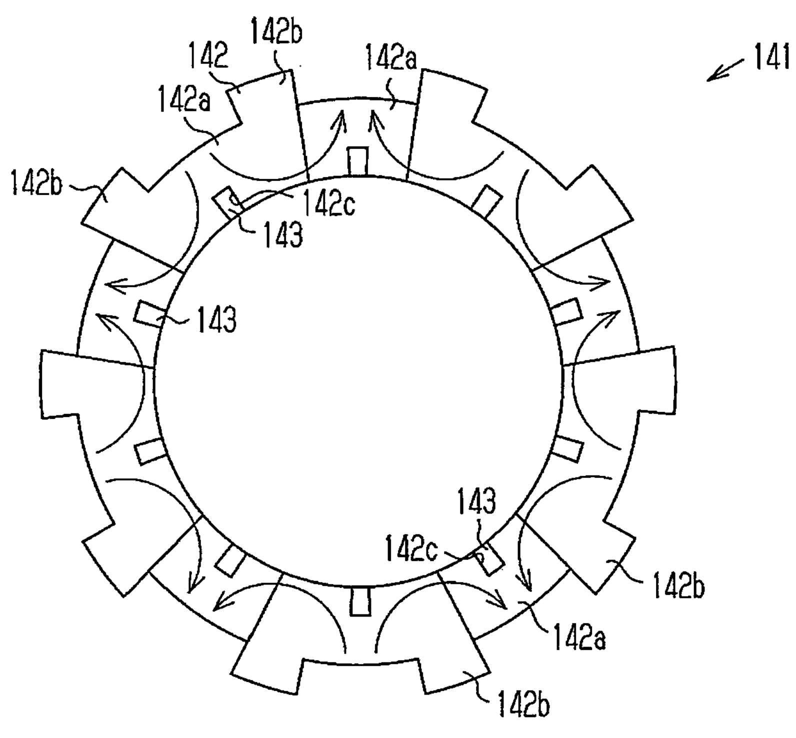
143
142b
142a
142c
142b

Fig.31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142a
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142c
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143
143
142c
142b
142a
142b

Fig.32

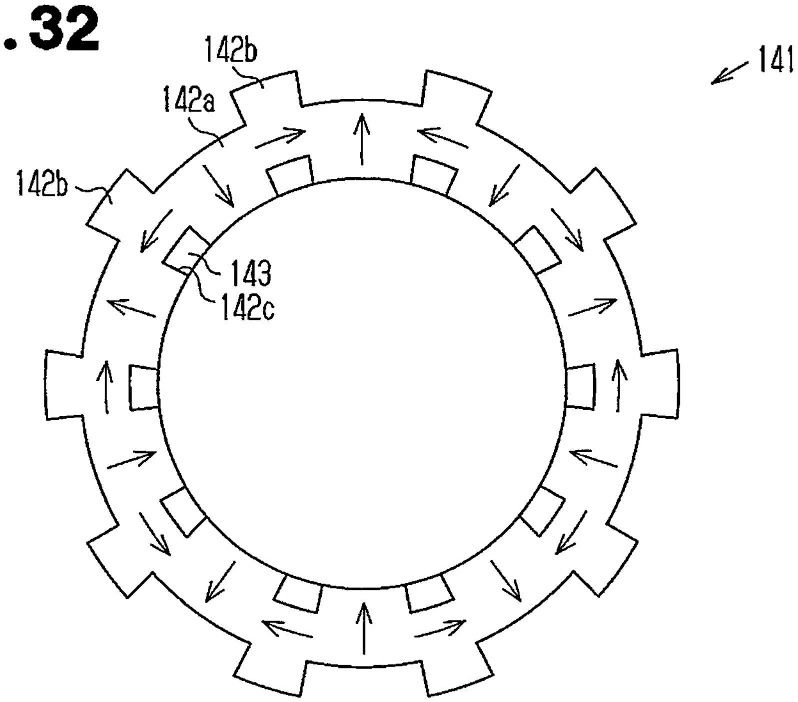


Fig.33

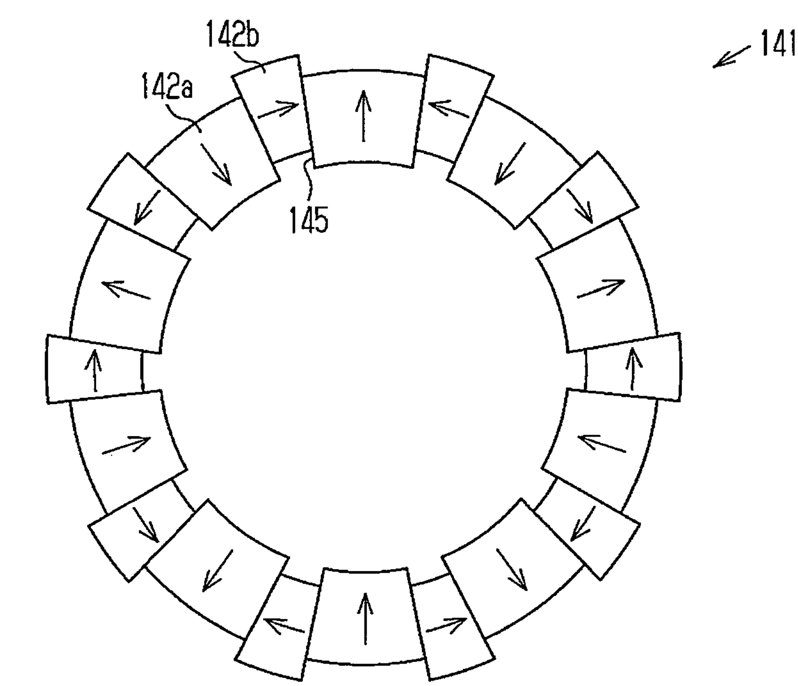


Fig.34A

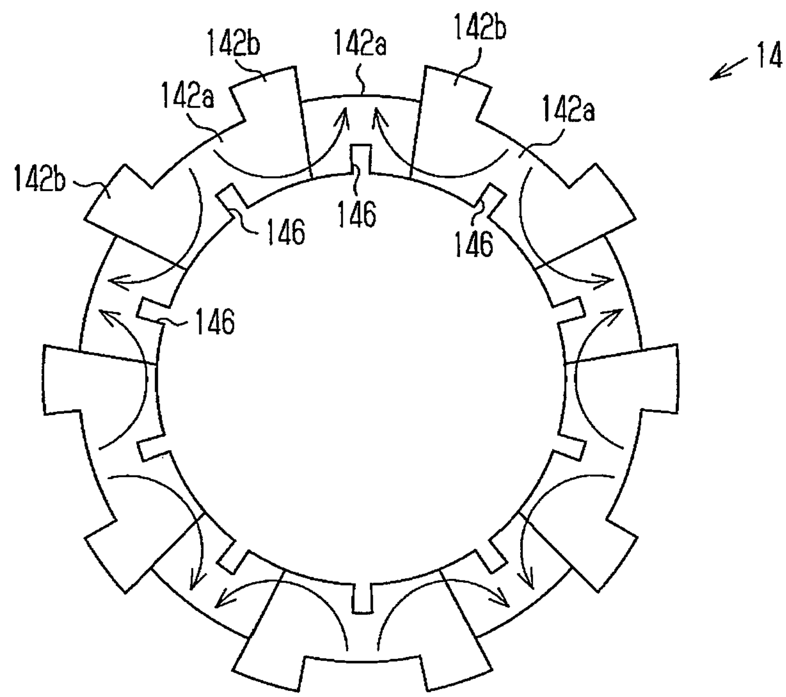


Fig.34B

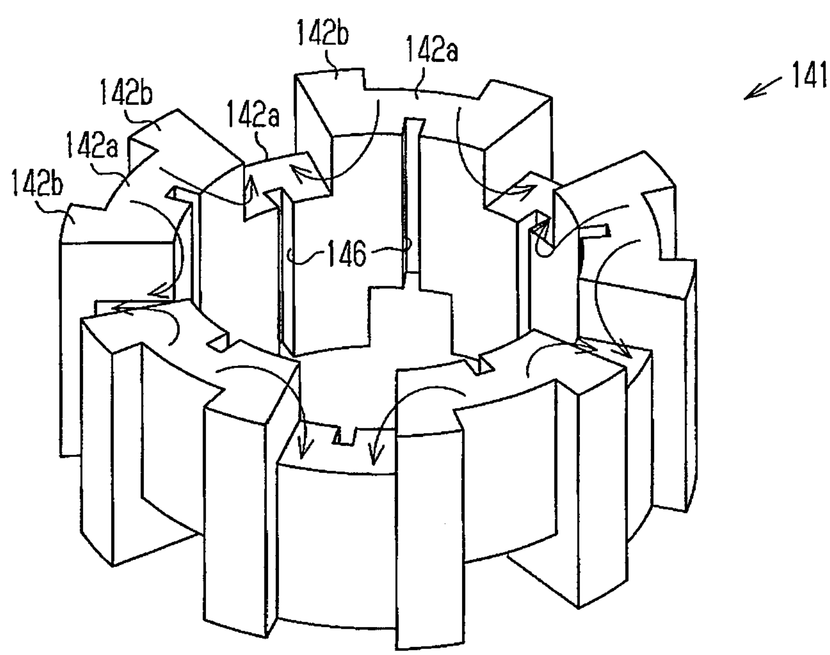
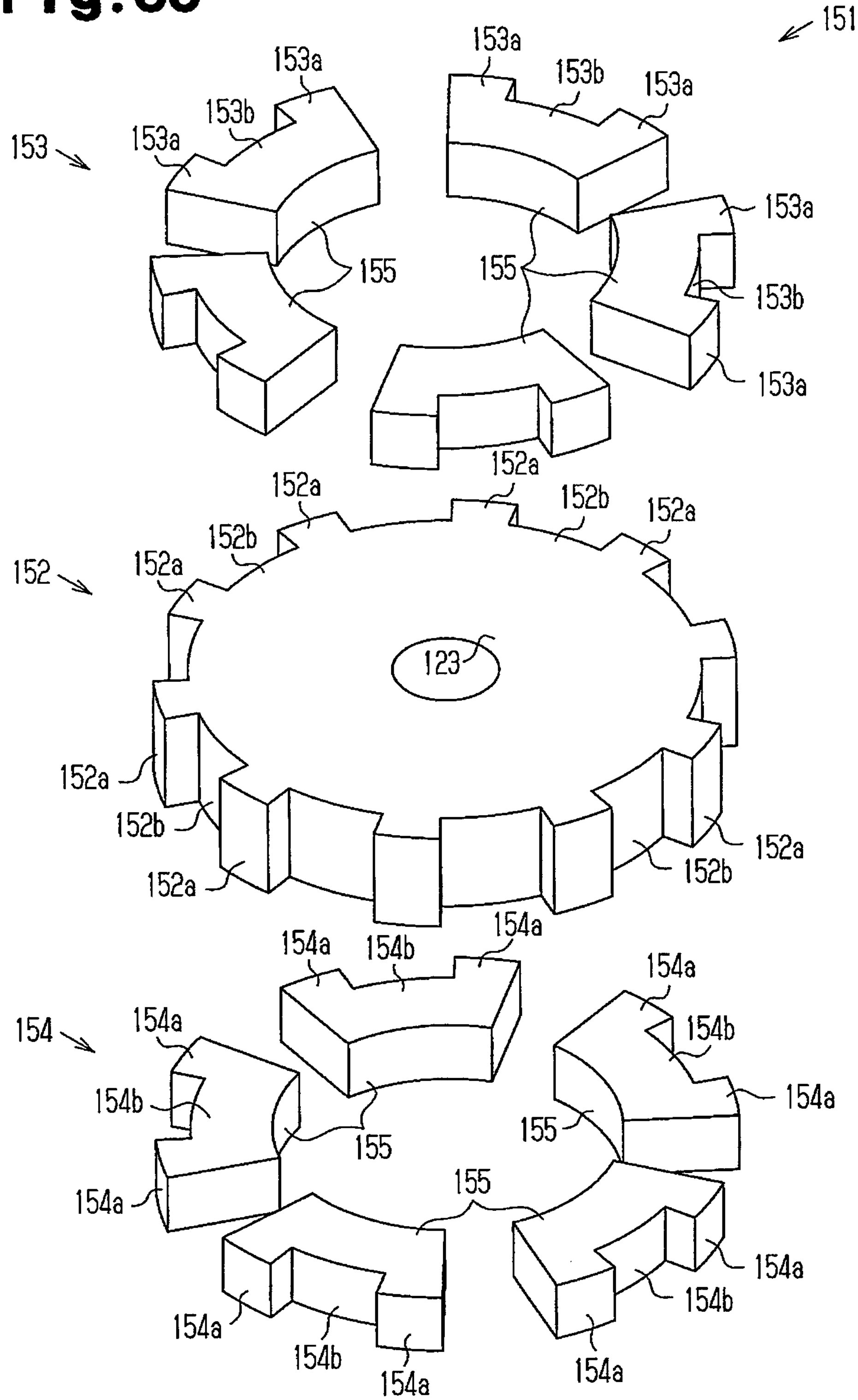


Fig.35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152b
152a
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152a
152b
152a
152a
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152a
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154a
154b
154a
154a
154b
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154b
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155
154a
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154a
154b
154a
154a
154b
154a
154a

Fig.36

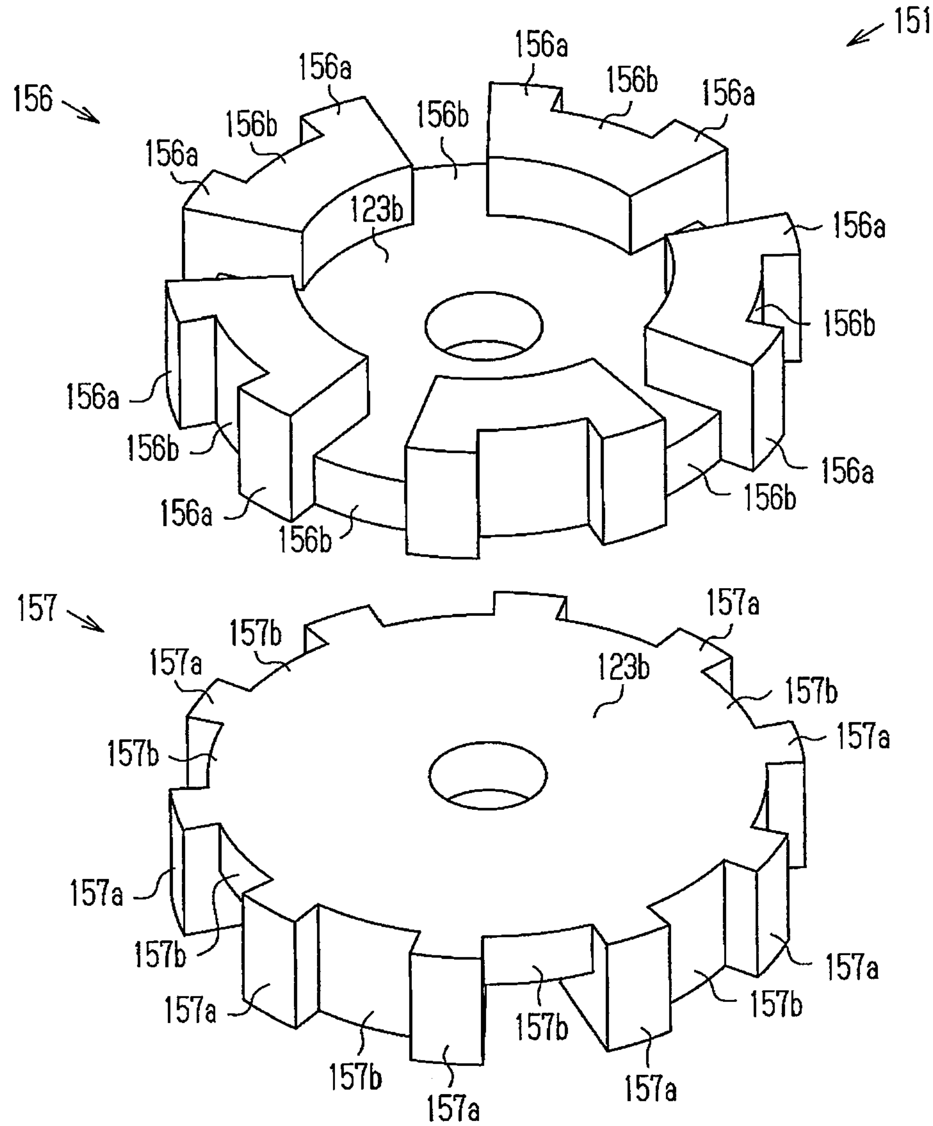
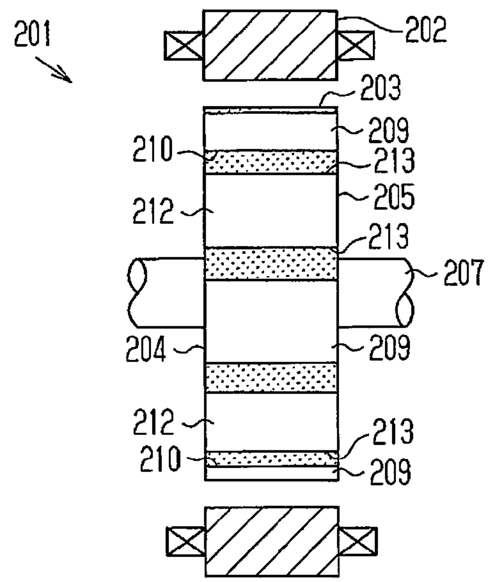


Fig.37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212
205
213
207
204
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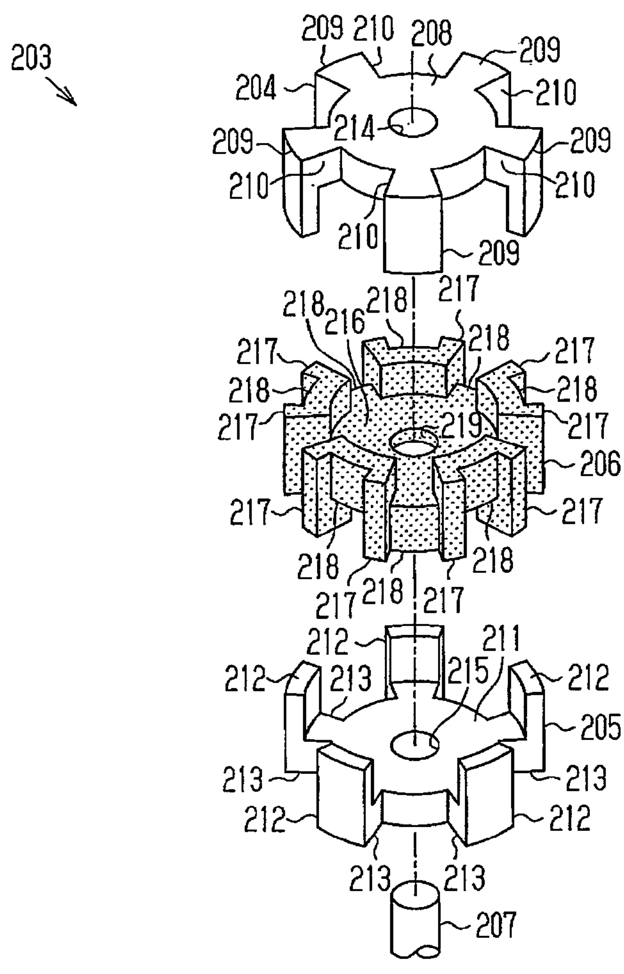
212
213
210
209

Fig.38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216 218
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205
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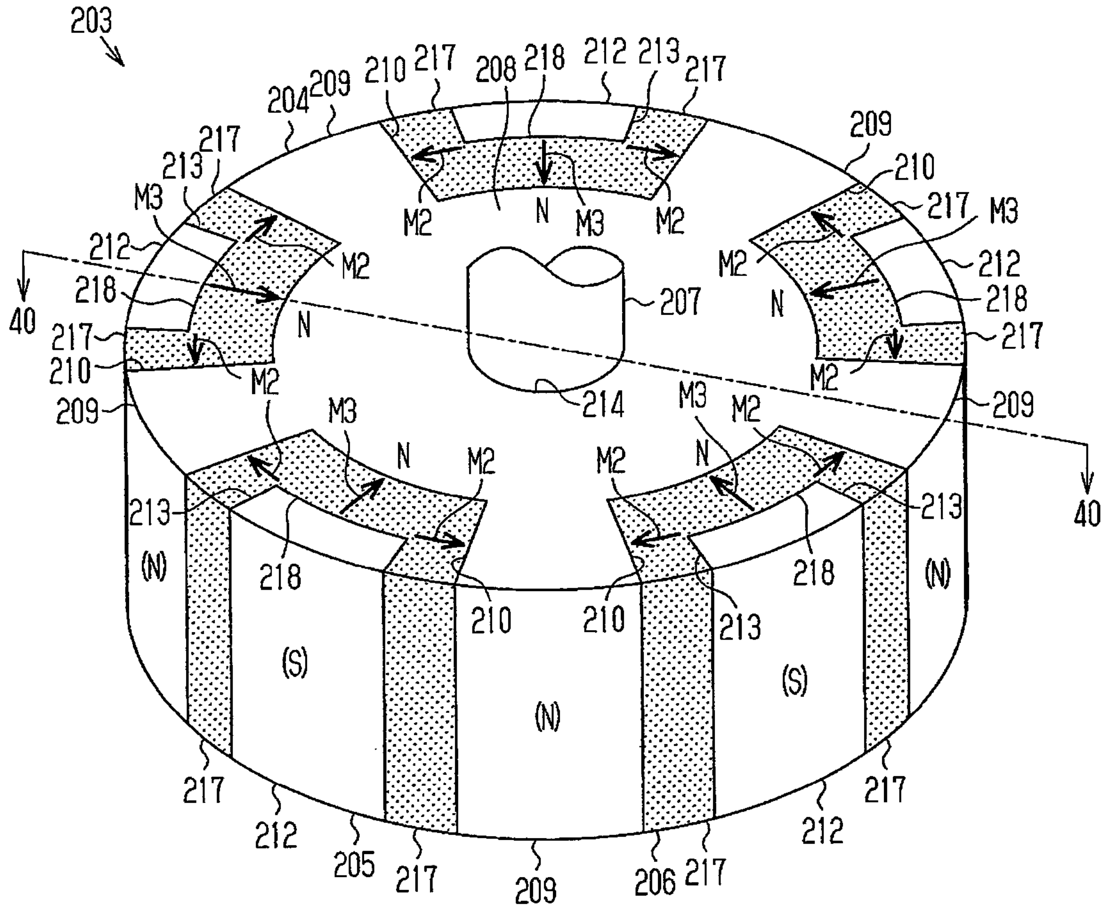
213 213
207

Fig.39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212
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214
217
218
M2
M3
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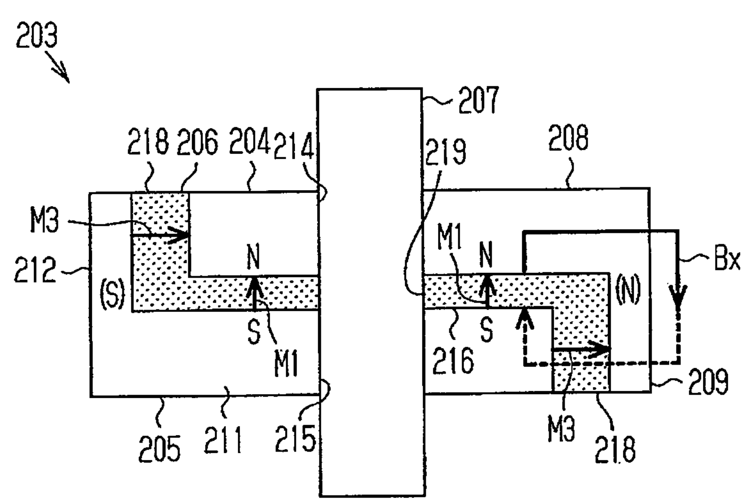
(S)
40

Fig.40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204
205
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214
215
216
218
219
M1
M3
N
S
(N)
(S)
Bx

Fig.41

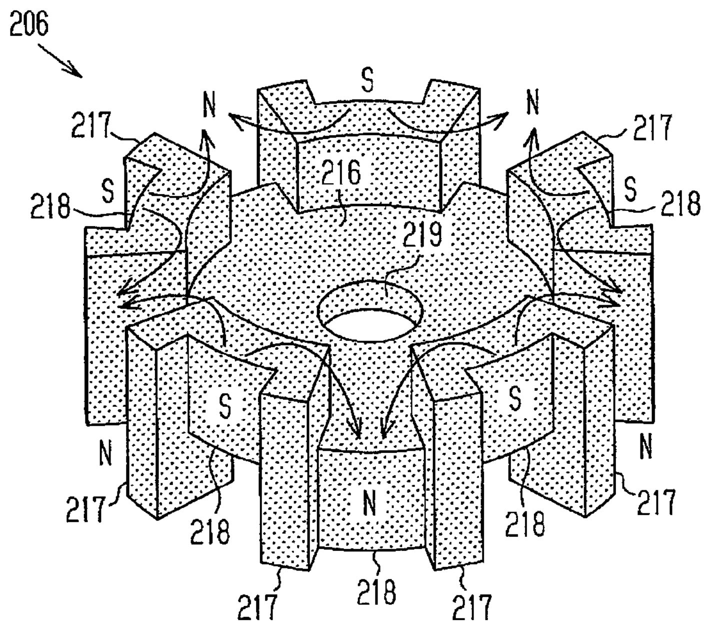


Fig.42A

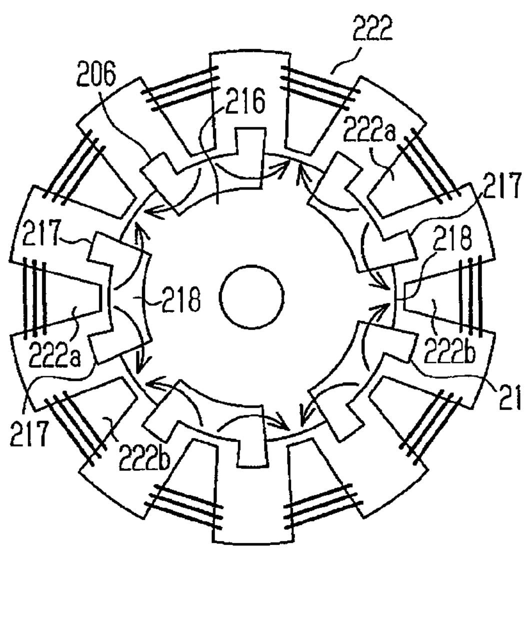


Fig.42B

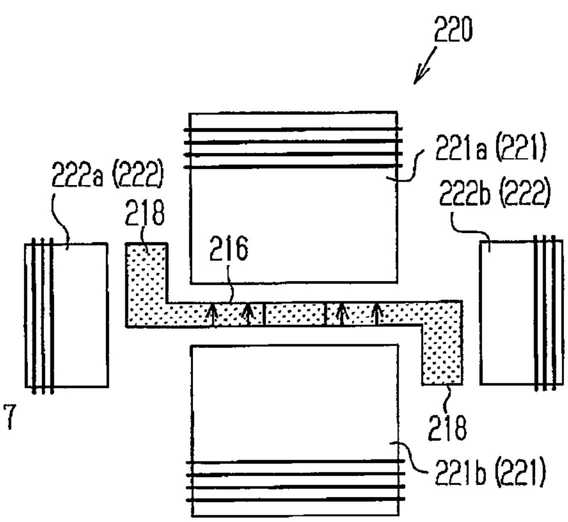
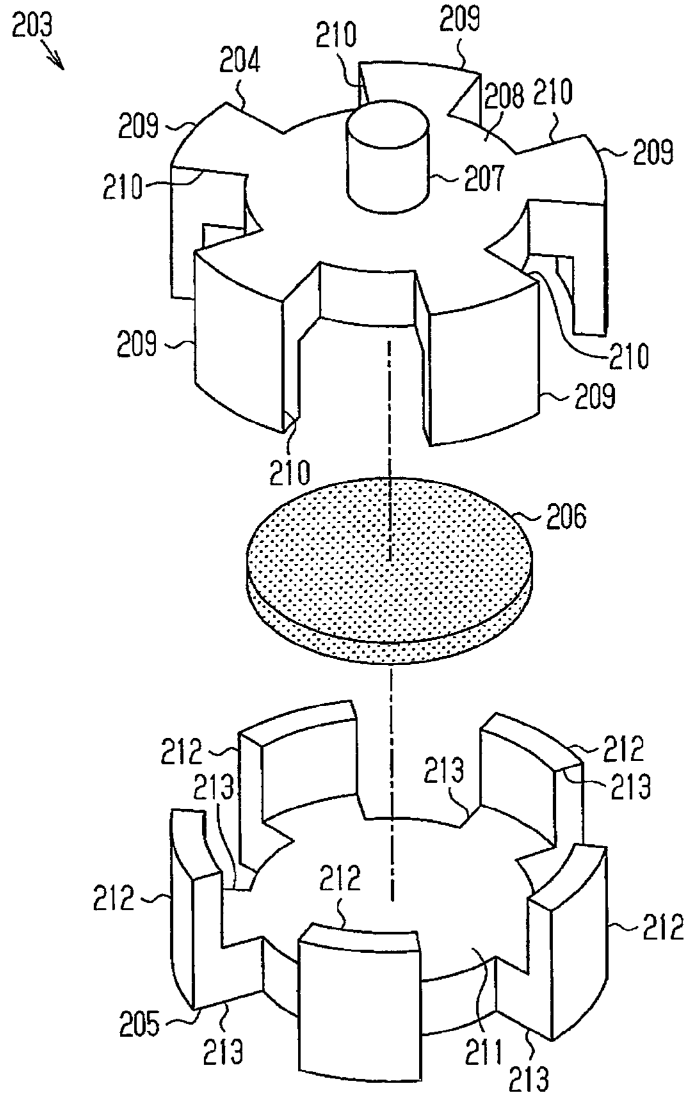


Fig. 43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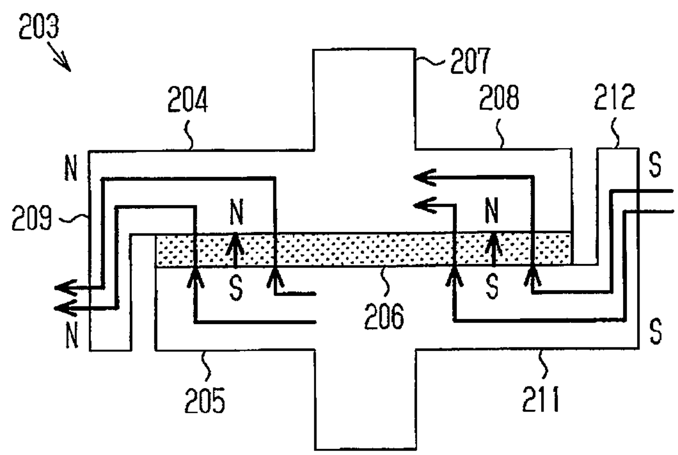
205
211

Fig. 44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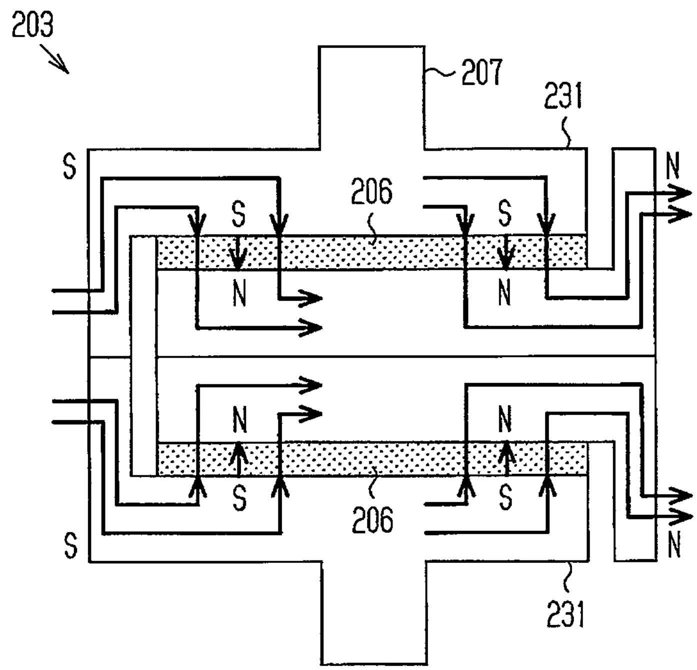
211

Fig. 45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207
231
206
S
N
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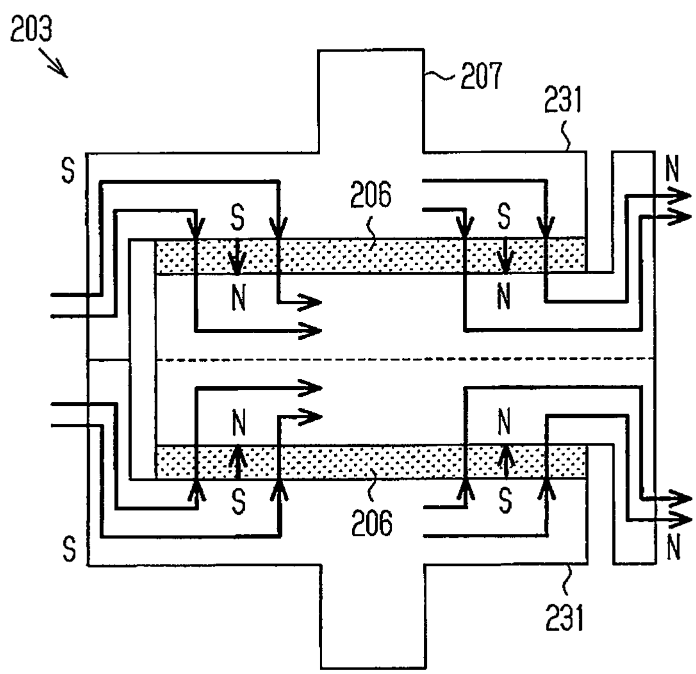
N
S
N
N
S
N
S
206
S
N
231

Fig. 46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S
N
S
N
S
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N
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N
S
206
S
N
231

Fig.47A

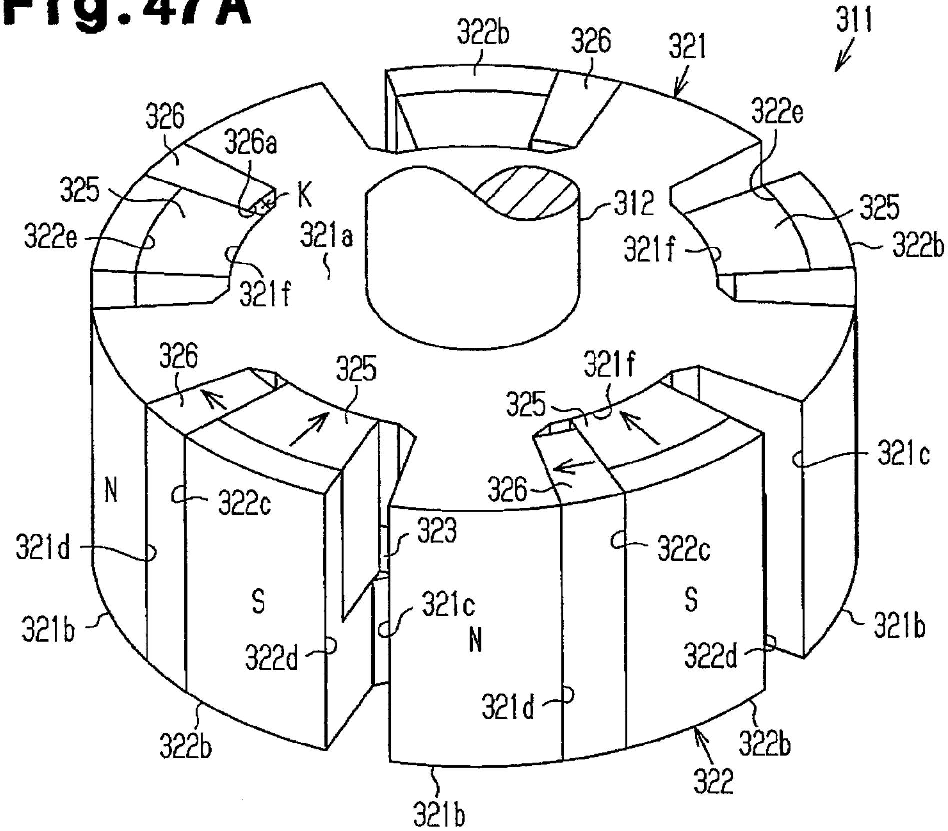


Fig.47B

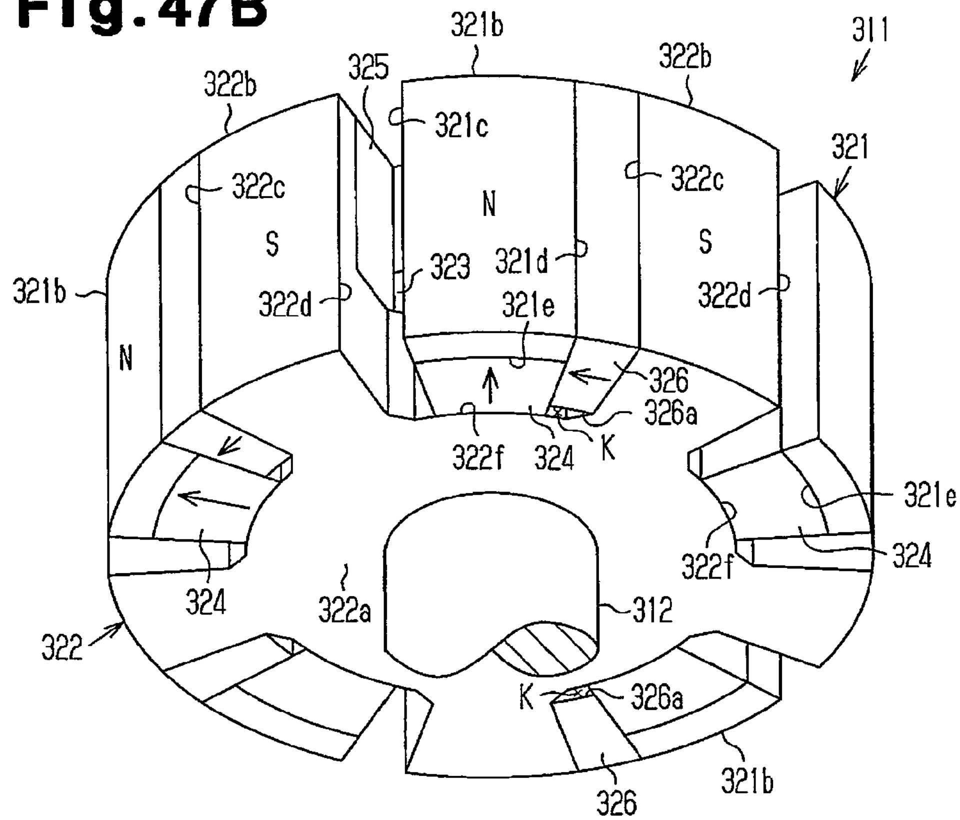
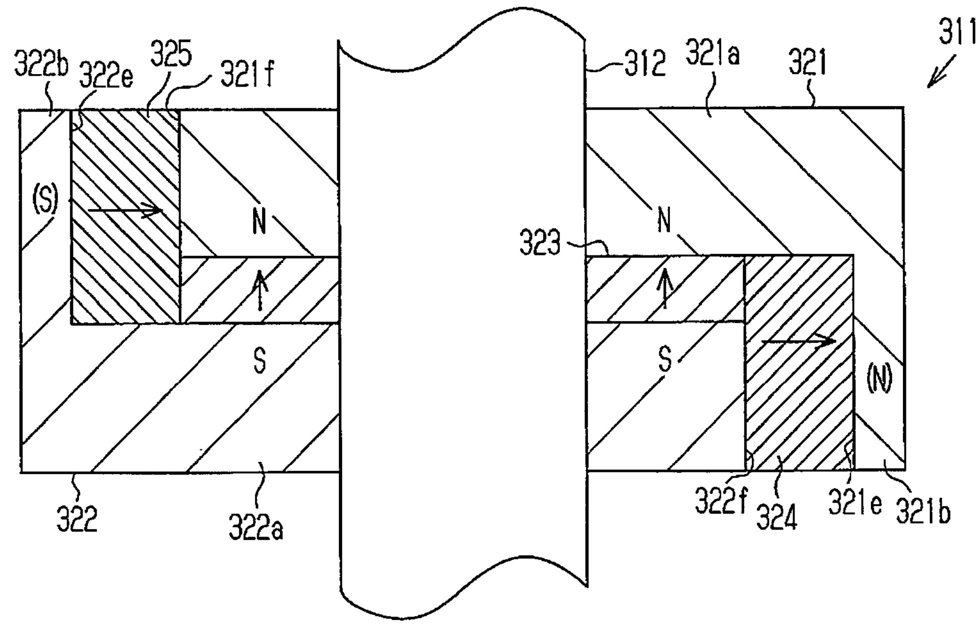


Fig.48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325
321f
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N
N
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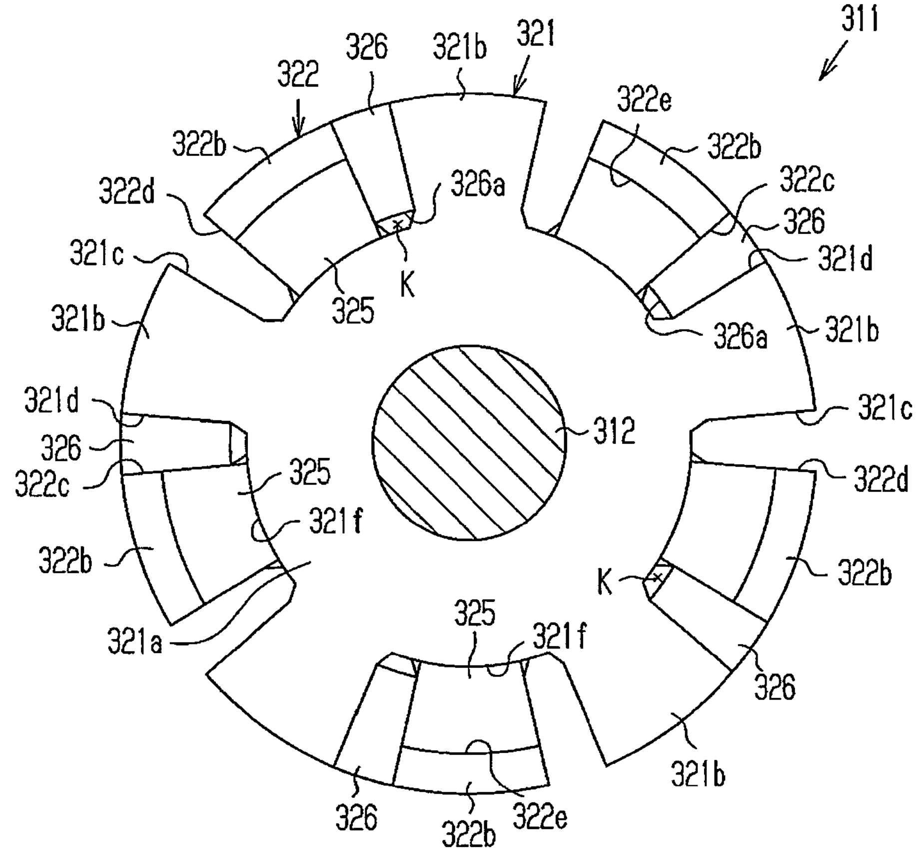
S
S
(N)
322
322a
322f
324
321e
321b

Fig.49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322e
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322d
326a
322c
326
321c
K
321d
321b
325
326a
321b
321d
321c
326
312
322c
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322d
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322b
322b
K
321a
325
321f
326
321b
326
322b
322e

Fig.50A

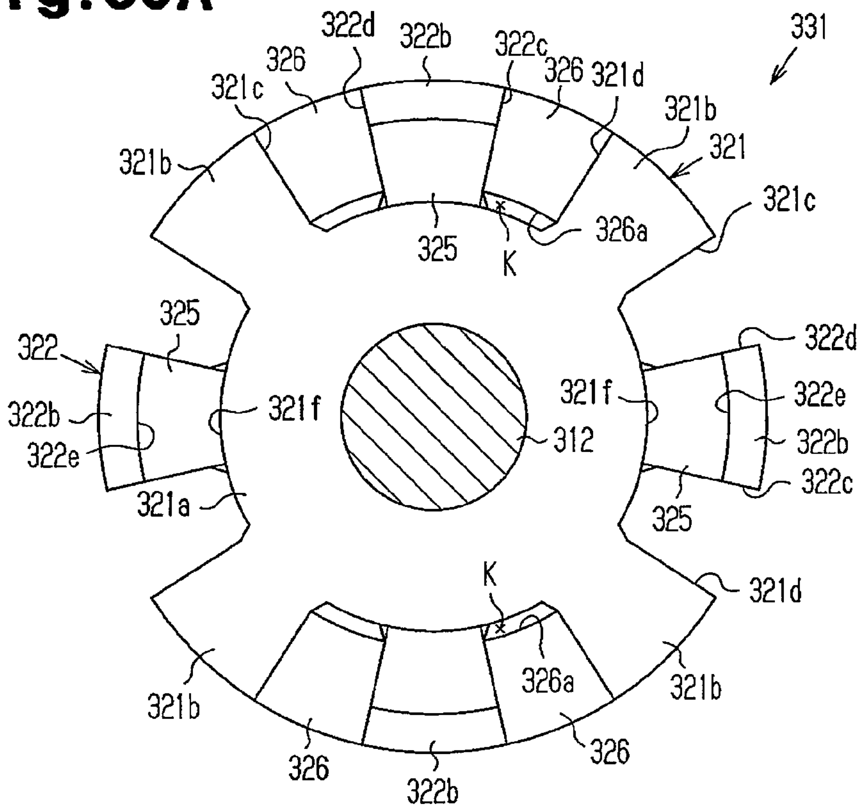


Fig.50B

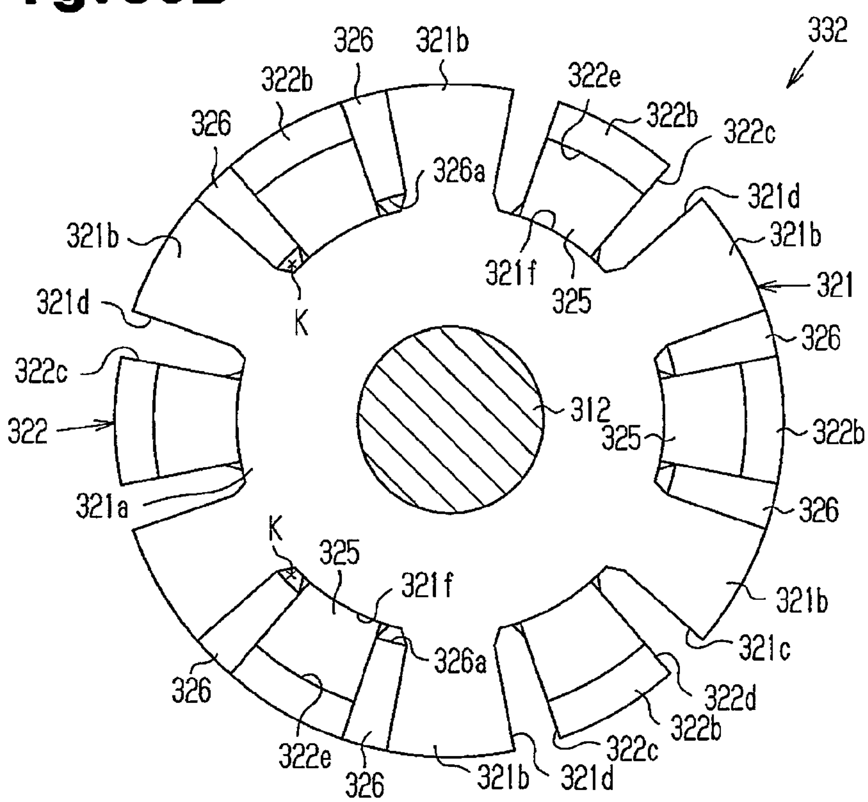
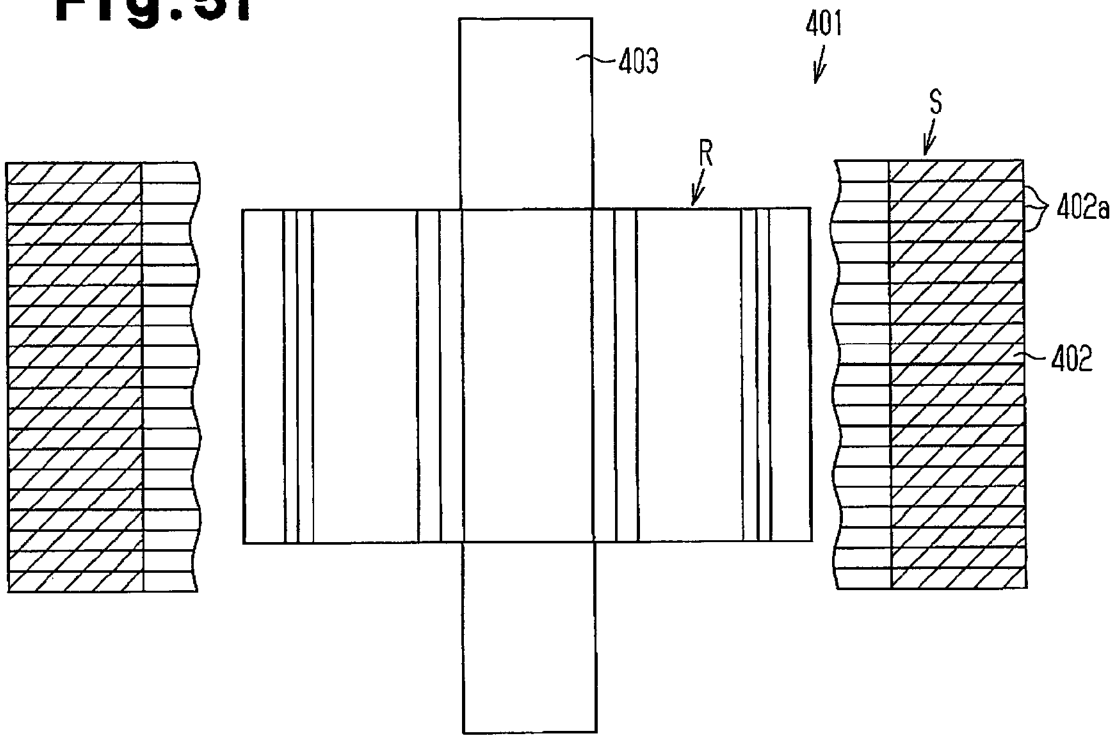
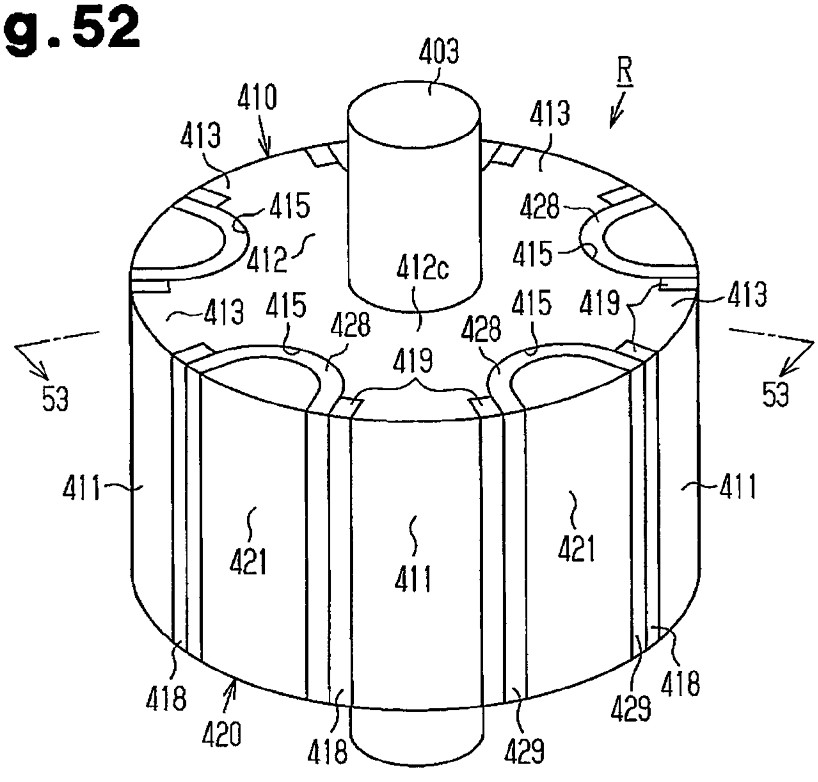


Fig.51



403
401
S
R
402a
402

Fig.52



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R
410
413
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415
428
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412c
415
413
415
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53
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421
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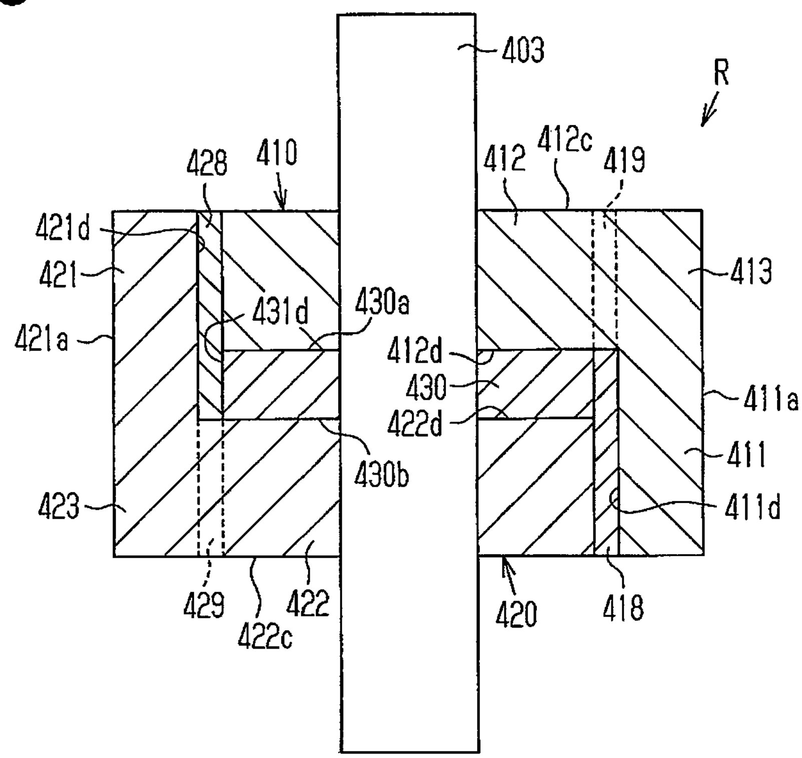
421
418
420
418
429
429
418

Fig.53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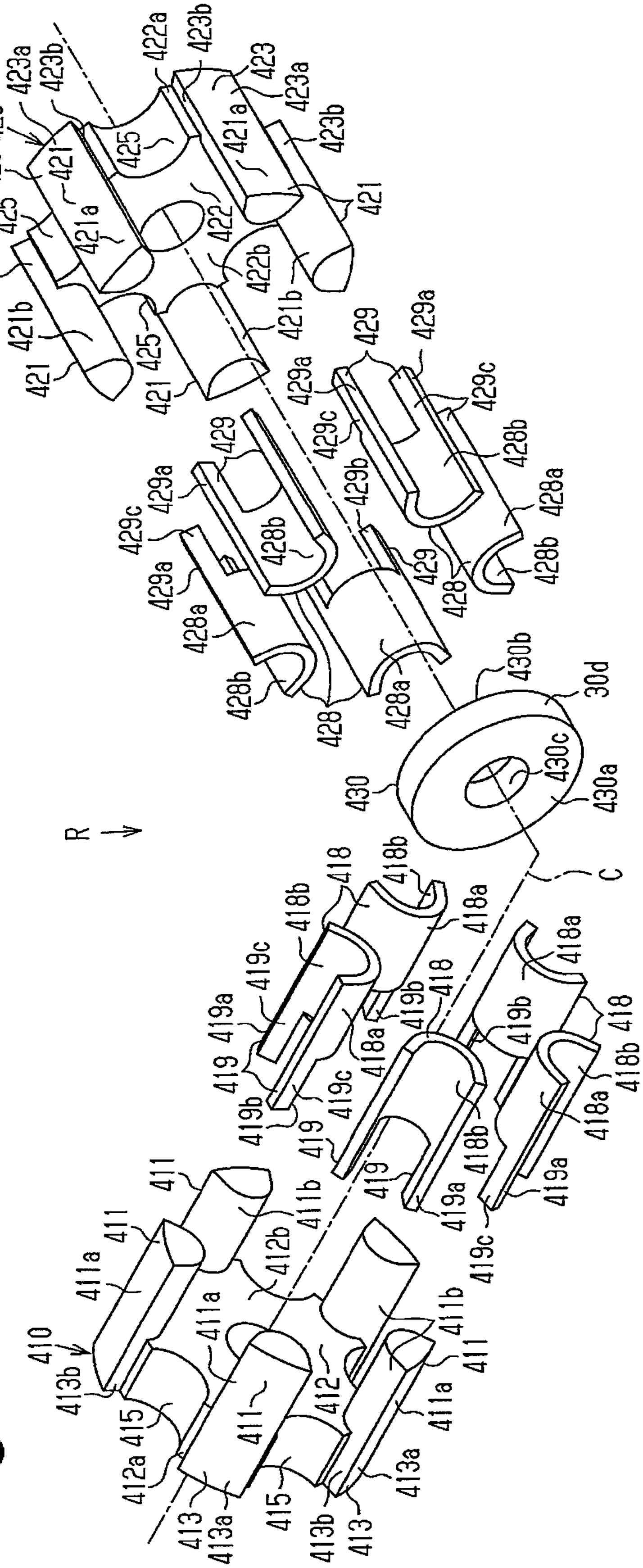
411d
429
422
420
418
422c

Fig. 54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428b
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429a
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429c
430
430a
430b
430c
30d
R
C
410
411
411a
411b
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412a
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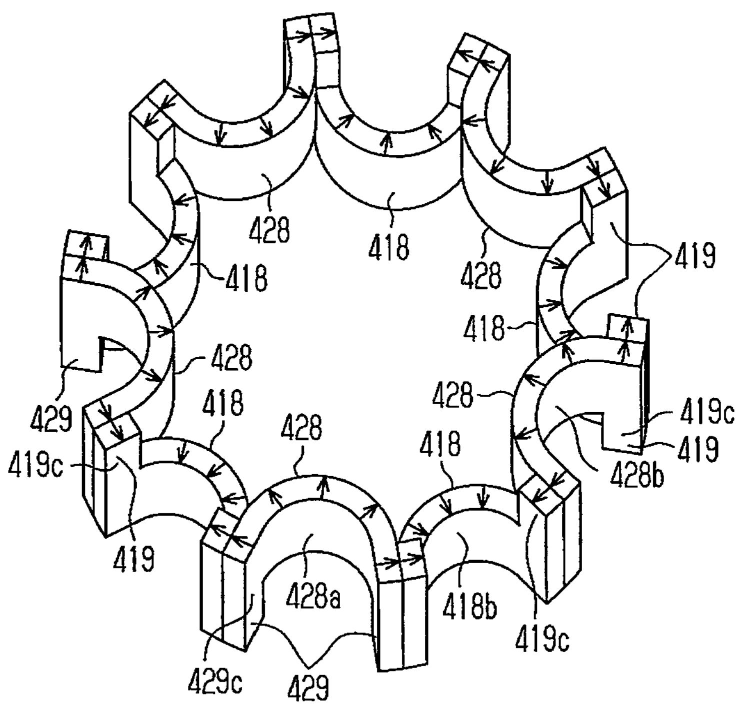
413
413a
413b
415
418
418a
418b
419
419a
419b
419c

Fig.55


428
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418
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419c
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428b
419
418b
428a
419c
429c
429

ROTOR AND MOTOR

BACKGROUND ART

The present invention relates to a rotor and a motor.

As a rotor used in a motor, a rotor with a Randell-type structure using a so-called permanent magnet field system is known (for example, refer to Japanese Laid-Open Utility Model Publication No. H5-43749), that includes combined rotor cores, each having a plurality of hook-shaped poles in a circumferential direction. A field magnet is arranged between the rotor cores to cause the hook-shaped poles to function alternately different in their magnetic poles.

In a motor that employs the above rotor, an output improvement is desired, while it is also desired to suppress the number of required components.

Further, in the rotor with the Randell-type structure using the permanent magnet field system, in order to achieve high output of the motor, rectifying magnets for rectifying magnetic paths are arranged between the plurality of hook-shaped poles that is arranged alternately in a circumferential direction. The rectifying magnets are also called interpolar magnets and are provided between respective poles. However, another rectifying magnet is required to be provided on a back surface side of each of the hook-shaped poles (at a surface facing a rotational axis in a radial direction). This increases the number of the rectifying magnets coupled to a single rotor. This requires time and labor for the coupling and increases costs.

SUMMARY OF THE INVENTION

A first object of the present invention is to provide a rotor that can contribute to increasing an output of a motor while suppressing an increase in the number of components, and a motor including such a rotor.

A second object of the present invention is to provide a rotor and a motor with which the number of components can be reduced, time and labor for the assembly can be reduced, and by which a low-cost and high-output motor can be realized.

To achieve the first object, one aspect of the present invention is a rotor provided with a first rotor core including a disk-shaped first core base and a plurality of first hook-shaped magnetic poles arranged at equal intervals on a peripheral portion of the first core base. Each of the first hook-shaped magnetic poles protrudes outward in a radial direction of the rotor and includes a first extended portion that extends along an axial direction of the rotor. A second rotor core includes a disk-shaped second core base and a plurality of second hook-shaped magnetic poles arranged at equal intervals on a peripheral portion of the second core base. Each of the second hook-shaped magnetic poles protrudes outward in the radial direction and includes a second extended portion that extends along the axial direction. The first and second hook-shaped magnetic poles are alternately arranged along a circumferential direction of the rotor in a state in which the first and second core bases are opposed in the axial direction. A field magnet is arranged between the first and second core bases in the axial direction. The field magnet is magnetized along the axial direction so that the first hook-shaped poles function as first poles and the second hook-shaped poles function as second poles. An auxiliary magnet includes at least two or more interpolar magnet portions, which are integrally formed. Each of the interpolar magnet portions is arranged in a void between the first hook-shaped poles and the second hook-shaped poles and magnetized in the circumferential direction.

To achieve the second object, a further aspect of the present invention includes a rotation shaft, a first rotor core including a first core base, which is fixed to the rotation shaft, and a plurality of first hook-shaped poles, which are arranged on the first core base at equal intervals and extend in an axial direction of the rotor. A second rotor core includes a second core base, which is fixed to the rotation shaft, and a plurality of second hook-shaped poles, which are arranged on the second core base at equal intervals and extend in the axial direction. Each of the second hook-shaped poles is arranged in a void between corresponding first hook-shaped poles. A field magnet is arranged between the first rotor core and the second rotor core. The field magnet is magnetized in the axial direction so that the first hook-shaped poles function as first poles and the second hook-shaped poles function as second poles. A plurality of first rectifying magnets each surrounds an entire inner surface of the first hook-shaped pole. Each of the first rectifying magnets is formed by a single member. A plurality of second rectifying magnets each surrounds an entire inner surface of the second hook-shaped poles. Each of the second rectifying magnets is formed by a single member.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. **1** is a sectional view of a motor according to the first embodiment of the present invention;

FIG. **2** is a perspective view of a rotor shown in FIG. **1**;

FIG. **3** is a partially exploded perspective view of the rotor shown in FIG. **1**;

FIG. **4** is a sectional view of the rotor shown in FIG. **1**;

FIG. **5** is a perspective view of a rotor according to the second embodiment of the present invention;

FIG. **6** is a sectional view of the rotor shown in FIG. **5**;

FIG. **7** is a side view of the rotor shown in FIG. **5**;

FIG. **8** is a perspective view of a rotor according to a further example;

FIG. **9** is an exploded perspective view of the rotor shown in FIG. **8**;

FIG. **10** is a perspective view of a rotor according to a further example;

FIG. **11** is an exploded perspective view of the rotor shown in FIG. **10**;

FIG. **12** is a sectional view of the rotor shown in FIG. **10**;

FIG. **13** is a perspective view of a rotor according to a further example;

FIG. **14** is an exploded perspective view of the rotor shown in FIG. **13**;

FIG. **15** is a perspective view of a rotor according to a further example;

FIG. **16** is an exploded perspective view of the rotor shown in FIG. **15**;

FIG. **17** is a perspective view of a rotor according to a further example;

FIG. **18** is an exploded perspective view of the rotor shown in FIG. **17**;

FIG. **19** is a perspective view of a rotor according to a further example;

FIG. **20** is a perspective view of a rotor according to a further example;

FIG. **21** is a perspective view of a rotor according to a third embodiment of the present invention;

FIG. **22** is a sectional view of the rotor shown in FIG. **21**;

FIG. **23** is a perspective view of an auxiliary magnet shown in FIG. **21**;

FIG. **24** is a perspective view of an auxiliary magnet according to a fourth embodiment of the present invention;

FIG. **25** is a perspective view of a circumferentially divided portion configuring the auxiliary magnet shown in FIG. **24**;

FIG. **26** is a perspective view of an auxiliary magnet according to a further example;

FIG. **27** is a perspective view of a circumferentially divided portion configuring the auxiliary magnet shown in FIG. **26**;

FIG. **28** is a perspective view of an auxiliary magnet according to a further example;

FIG. **29** is a perspective view of an auxiliary magnet according to a further example;

FIG. **30** is a plan view of an auxiliary magnet according to a fifth embodiment of the present invention;

FIG. **31** is a plan view of an auxiliary magnet according to a further example;

FIG. **32** is a plan view of an auxiliary magnet according to a further example;

FIG. **33** is a plan view of an auxiliary magnet according to a further example;

FIG. **34**A is a plan view of an auxiliary magnet according to a further example;

FIG. **34**B is a perspective view of the auxiliary magnet according to the further example shown in FIG. **34**B;

FIG. **35** is a perspective view of an auxiliary magnet according to a sixth embodiment of the present invention;

FIG. **36** is a perspective view of an auxiliary magnet according to a further example;

FIG. **37** shows the structure of a motor according to the seventh embodiment of the present invention;

FIG. **38** is an exploded perspective view showing a component configuration of the rotor shown in FIG. **37**;

FIG. **39** is a perspective view showing an outer appearance of the rotor shown in FIG. **37**;

FIG. **40** is a sectional view along a line **40-40** in FIG. **39**, describing a magnetic field generated in the rotor;

FIG. **41** is a perspective view showing a configuration of an integrated permanent magnet according to a further example;

FIGS. **42**A and **42**B are explanatory diagrams, respectively describing a method of magnetizing the integrated permanent magnet;

FIG. **43** is an exploded perspective view showing a component configuration of a rotor according to a further example;

FIG. **44** is a sectional view describing a magnetic field generated in the rotor;

FIG. **45** is a sectional view of a rotor according to a yet further example;

FIG. **46** is a sectional view of a rotor according to a yet further example;

FIGS. **47**A and **47**B are perspective views of a rotor according to an eighth embodiment of the present invention;

FIG. **48** is a sectional view of the rotor shown in FIG. **47**;

FIG. **49** is a plan view of the rotor shown in FIG. **47**A;

FIGS. **50**A and **50**B are plan views of a rotor according to a further example;

FIG. **51** is a sectional view of a brushless motor according to a ninth embodiment of the present invention;

FIG. **52** is a perspective view of the rotor shown in FIG. **51**;

FIG. **53** is a sectional view along a line **53-53** in FIG. **52**;

FIG. **54** is an exploded perspective view of the rotor shown in FIG. **52**; and

FIG. **55** is a perspective view describing magnetized directions of first and second rectifying magnets shown in FIG. **52**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

A first embodiment of the present invention will be described below with reference to FIG. **1** to FIG. **4**.

As shown in FIG. **1**, a motor casing **2** of a motor **1** includes a cylindrical housing **3** formed in a bottomed cylinder shape, and a front end plate **4** that closes an opening of the cylindrical housing **3** on a front side (left side in FIG. **1**). Further, a circuit containing box **5** that contains a power circuit such as a circuit board and the like is attached to an end portion of the cylindrical housing **3** on a rear side (right side in FIG. **1**).

A stator **6** is fixed to an inner circumferential surface of the cylindrical housing **3**. The stator **6** includes an armature core **7** including a plurality of teeth extending radially inward, and a segment conductor (SC) wire **8** which is wound around each tooth of the armature core **7**.

A rotor **11** of the motor **1** includes a rotation shaft **12**, and is arranged inside the stator **6**. The rotation shaft **12** is a metal shaft made of a non-magnetic body, and is rotatably supported by bearings **13**, **14**, which are supported by a bottom portion **3***a* of the cylindrical housing **3** and the front end plate **4**.

As shown in FIG. **2** to FIG. **4**, the rotor **11** includes first and second rotor cores **21**, **22**, a ring magnet **23** as a field magnet (see FIG. **4**), first and second back auxiliary magnets **24**, **25** as back auxiliary magnets (see FIG. **3** and FIG. **4**), and first and second integrated auxiliary magnets **26**, **27** as an integrated auxiliary magnet.

The first rotor core **21** has, on an outer circumferential part of a first core base **21***a* that is a disk-shaped core base, first hook-shaped magnetic poles **21***b* as a plurality (five in this embodiment) of hook-shaped poles arranged at equal intervals to protrude outward in a radial direction and extend in an axial direction. Circumferential end surfaces **21***c*, **21***d* of each first hook-shaped magnetic pole **21***b* are flat surfaces that extend in the radial direction (without being sloped relative to the radial direction when seen from the axial direction), and the first hook-shaped magnetic pole **21***b* has a cross-section in an axially orthogonal direction with a triangular shape. Further, a width (angle) in the circumferential direction of each first hook-shaped magnetic pole **21***b*, that is, the width (angle) in the circumferential direction between the circumferential end surfaces **21***c*, **21***d* is set to be smaller than a width (angle) of a gap between the first hook-shaped magnetic poles **21***b* that are adjacent in the circumferential direction. Further, each first hook-shaped magnetic pole **21***b* is formed in a rectangular shape as seen from outside in the radial direction.

Further, the second rotor core **22** has a same shape as the first rotor core **21**, and has, on a peripheral portion of a second core base **22***a* that is a disk-shaped core base, second hook-shaped magnetic poles **22***b* as a plurality (five in this embodiment) of hook-shaped poles arranged at equal intervals to protrude outward in the radial direction and extend in the axial direction. Further, circumferential end surfaces **22***c*, **22***d* of each second hook-shaped magnetic pole **22***b* are flat surfaces that extend in the radial direction (without being sloped relative to the radial direction when seen from the axial direction), and the second hook-shaped magnetic pole **22***b* has a cross-section in an axially orthogonal direction with a triangular shape. Further, a width (angle) in the circumferential direction of each second hook-shaped magnetic pole **22***b*, that is, the width (angle) in the circumferential direction between the circumferential end surfaces **22***c*, **22***d* is set to be smaller than a width (angle) of a gap between the second hook-shaped magnetic poles **22***b* that are adjacent in the circumferential direction. Further, each second hook-shaped magnetic pole **22***b* is formed in a rectangular shape as seen from outside in the radial direction. Further, the second rotor core **22** is assembled onto the first rotor core **21** such that the second hook-shaped magnetic poles **22***b* are arranged respectively in a corresponding void between the first hook-shaped magnetic poles **21***b* (that is, arranged alternately with the first hook-shaped magnetic poles **21***b* in the circumferential direction), and further, as shown in FIG. **4**, such that the ring magnet **23** is arranged (sandwiched) in the axial direction between the first core base **21***a* and the second core base **22***a* that oppose one another. Notably, at this occasion, a rectangular groove as seen from the outside in the radial direction is formed between the first hook-shaped magnetic poles **21***b* and the second hook-shaped magnetic poles **22***b* in the circumferential direction (see FIG. **3**).

The ring magnet **23** has an outer diameter set to be same as an outer diameter of each of the first and second core bases **21***a*, **22***a*, and is magnetized in the axial direction so as to cause the first hook-shaped poles **21***b* to function as first poles (N poles in the embodiment) and the second hook-shaped poles **22***b* to function as second poles (S poles in the embodiment).

Further, as shown in FIG. **3** and FIG. **4**, the first back auxiliary magnet **24** is arranged between a back surface (inside surface in the radial direction) of each first hook-shaped pole **21***b* and an outer circumferential surface of the second core base **22***a*. The first back auxiliary magnet **24** has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape. In order to reduce magnetic flux leakage at that portion, the first back auxiliary magnet **24** is magnetized in the radial direction so as to cause a side in contact with the back surface of the first hook-shaped pole **21***b* to be magnetized to the N pole similar to the first hook-shaped pole **21***b*, and a side in contact with the second core base **22***a* to be magnetized to the S pole similar to the second core base **22***a*.

Further, as shown in FIG. **3** and FIG. **4**, the second back auxiliary magnet **25** is arranged between a back surface (inside surface in the radial direction) of each second hook-shaped pole **22***b* and an outer circumferential surface of the first core base **21***a*. The second back auxiliary magnet **25** has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape; and in order to reduce magnetic flux leakage at that portion, the second back auxiliary magnet **25** is magnetized in the radial direction so as to cause a side in contact with the back surface of the second hook-shaped pole **22***b* to be magnetized to the S pole similar to the second hook-shaped pole **22***b*, and a side in contact with the first core base **21***a* to be magnetized to the N pole similar to the first core base **21***a*.

Further, as shown in FIG. **4**, arrangement positions of each first back auxiliary magnet **24** and each second back auxiliary magnet **25** are set such that they overlap one another in the axial direction at a position in the axial direction where the ring magnet **23** is arranged, that is, in other words, such that they are arranged also across the position in the axial direction where the ring magnet **23** is to be arranged.

Further, the first and second integrated auxiliary magnets **26**, **27** are assembled to the first and second rotor cores **21**, **22**.

As shown in FIG. **2** and FIG. **3**, the first integrated auxiliary magnet **26** is configured by first and second interpolar magnet portions **26***a*, **26***b* as interpolar magnet portions provided between the first hook-shaped poles **21***b* and the second hook-shaped poles **22***b* in the circumferential direction, and a first axially covering magnet portion **26***c* as an axially covering magnet portion provided to cover an outer surface of the first core base **21***a* in the axial direction, which are formed integrally.

The first axially covering magnet portion **26***c* is formed in a disk shape having a center hole through which the rotation shaft **12** is to be inserted, and an outer diameter thereof is set to be same as an outer diameter of each of the first and second cores **21**, **22** (rotor **11**). The first axially covering magnet portion **26***c* is provided to cover an entirety of a plan surface of the first rotor core **21** on a side without protrusion of the first hook-shaped poles **21***b* (one end surface in the axial direction including the first core base **21***a*). Further, the first axially covering magnet portion **26***c* is magnetized in the axial direction so as to reduce magnetic flux leakage at that portion (from the end surface of the first core base **21***a* in the axial direction).

Further, the first interpolar magnet portions **26***a* are formed to extend in the axial direction from an outer circumferential side of a plan surface of the first axially covering magnet portion **26***c*, and a plurality of them (five in the embodiment) is formed at equal intervals. Further, an axial length of each first interpolar magnet portion **26***a* is set to be half an axial length of each of the first and second hook-shaped poles **21***b*, **22***b*. Further, each first interpolar magnet portion **26***a* has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape, and is arranged between a flat surface formed by the circumferential end surface **21***c* of the first hook-shaped pole **21***b* at one side and a circumferential end surface of the first back auxiliary magnet **24**, and a flat surface formed by the circumferential end surface **22***d* of the second hook-shaped pole **22***b* at the other side and a circumferential end surface of the second back auxiliary magnet **25**.

Further, the second interpolar magnet portions **26***b* are formed to extend in the axial direction from the outer circumferential side of the plan surface of the first axially covering magnet portion **26***c* between the first interpolar magnet portions **26***a*, and a plurality of them (five in the embodiment) is formed at equal intervals. Further, an axial length of each second interpolar magnet portion **26***b* is set to be half the axial length of each of the first and second hook-shaped poles **21***b*, **22***b*. Further, each second interpolar magnet portion **26***b* has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape, and is arranged between a flat surface formed by the circumferential end surface **21***d* of the first hook-shaped pole **21***b* at the other side and a circumferential end surface of the first back auxiliary magnet **24**, and a flat surface formed by the circumferential end surface **22***c* of the second hook-shaped pole **22***b* at one side and a circumferential end surface of the second back auxiliary magnet **25**. Further, the first and second interpolar magnet portions **26***a*, **26***b* are magnetized in the circumferential direction so as to have the same polarities as the first and second hook-shaped poles **21***b*, **22***b* respectively (at the first hook-shaped pole **21***b* side the N pole and at the second hook-shaped pole **22***b* side the S pole) in order to reduce magnetic flux leakage at that portions.

As shown in FIG. **2** and FIG. **3**, the second integrated auxiliary magnet **27** is formed in a same shape as the first integrated auxiliary magnet **26**. That is, the second integrated auxiliary magnet **27** is configured by first and second interpolar magnet portions **27***a*, **27***b* as interpolar magnet portions provided between the first hook-shaped poles **21***b* and the second hook-shaped poles **22***b* in the circumferential direction, and a second axially covering magnet portion **27**c as an axially covering magnet portion provided to cover an outer surface of the second core base **22**a in the axial direction being formed integrally.

The second axially covering magnet portion **27**c is formed in a disk shape having a center hole through which the rotation shaft **12** is inserted, and an outer diameter thereof is set to be same as the outer diameter of each of the first and second cores **21**, **22** (rotor **11**). The second axially covering magnet portion **27**c is provided to cover an entirety of a plan surface of the second rotor core **22** on a side without protrusion of the second hook-shaped poles **22**b (one end surface in the axial direction including the second core base **22**a). Further, the second axially covering magnet portion **27**c is magnetized in the axial direction so as to reduce magnetic flux leakage at that portion (from the end surface of the second core base **22**a in the axial direction).

Further, the first interpolar magnet portions **27**a are formed to extend in the axial direction from an outer circumferential side of a plan surface of the respective second axially covering magnet portions **27**c, and a plurality of them (five in the embodiment) is formed at equal intervals. Further, an axial length of each first interpolar magnet portion **27**a is set to be half the axial length of each of the first and second hook-shaped poles **21**b, **22**b. Further, each first interpolar magnet portion **27**a has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape, and is arranged between the flat surface formed by the circumferential end surface **21**c of the first hook-shaped pole **21**b at the one side and the circumferential end surface of the first back auxiliary magnet **24**, and the flat surface formed by the circumferential end surface **22**d of the second hook-shaped pole **22**b at the other side and the circumferential end surface of the second back auxiliary magnet **25**.

Further, the second interpolar magnet portions **27**b are formed to extend in the axial direction from the outer circumferential side of the plan surface of the respective second axially covering magnet portions **27**c between the first interpolar magnet portions **27**a, and a plurality of them (five in the embodiment) is formed at equal intervals. Further, an axial length of each second interpolar magnet portion **27**b is set to be half the axial length of each of the first and second hook-shaped poles **21**b, **22**b. Further, each second interpolar magnet portion **27**b has a substantially rectangular parallelepiped shape having a cross-section in the axially orthogonal direction with a triangular shape, and is arranged between the flat surface formed by the circumferential end surface **21**d of the first hook-shaped pole **21**b at the other side and the circumferential end surface of the first back auxiliary magnet **24**, and the flat surface formed by the circumferential end surface **22**c of the second hook-shaped pole **22**b at the one side and the circumferential end surface of the second back auxiliary magnet **25**. Further, the first and second interpolar magnet portions **27**a, **27**b are magnetized in the circumferential direction so as to have same polarities as the first and second hook-shaped poles **21**b, **22**b respectively (at the first hook-shaped pole **21**b side the N pole and at the second hook-shaped pole **22**b the S pole) in order to reduce magnetic flux leakage at that portions.

Next, operation of the motor **1** will be described.

In the rotor **11**, the magnetic flux leakage can be reduced at the respective positions where the first and second back auxiliary magnets **24**, **25**, and the first and second integrated auxiliary magnets **26**, **27** (the first and second interpolar magnet portions **26**a, **27**a, **26**b, **27**b, and the first and second axially covering magnet portions **26**c, **27**c) are arranged, whereby the rotor **11** can use magnetic flux of the ring magnet **23** effectively for the output of the motor **1**.

Next, advantages that are characteristic to the first embodiment will be described below.

(1) Since the first and second interpolar magnet portions **26**a, **27**a, **26**b, **27**b that are magnetized in the circumferential direction are provided between the first and second hook-shaped poles **21**b, **22**b in the circumferential direction, the magnetic flux leakage at that portions (between the first hook-shaped magnetic poles **21**b and the second hook-shaped magnetic poles **22**b) can be reduced. Further, since the first and second axially covering magnet portions **26**c, **27**c are provided on the outer surfaces of the first and second core bases **21**a, **22**a in the axial direction, the magnetic flux leakage at that portions (from the end surfaces of the first and second core bases **21**a, **22**a in the axial direction) can be reduced. As a result, the magnetic flux of the ring magnet **23** can effectively be used for the output of the motor **1**, and for example, high efficiency and high output can be achieved. Further, since a large number of components, i.e., the first and second interpolar magnet portions **26**a, **27**a, **26**b, **27**b and the first and second axially covering magnet portions **26**c, **27**c are formed integrally into the first and second integrated auxiliary magnets **26**, **27**, the number of components can be reduced compared to a case of providing the same with separately formed components. As a result, for example, component management and assembly become easy. In addition, in the case of assembling the interpolar magnet portions (the first and second interpolar magnet portions **26**a, **27**a, **26**b, **27**b) separately formed, any configuration that would prevent the interpolar magnet portions from projecting outward in the radial direction becomes necessary. However, such a configuration can be omitted.

(2) Since the first and second axially covering magnet portions **26**c, **27**c are provided at both end surfaces of the rotor **11** in the axial direction, the magnetic flux leakage from the both end surfaces in the axial direction is reduced, and the magnetic flux leakage can further be reduced compared to a case of the axially covering magnet portion only on one end surface in the axial direction, for example.

(3) Since the first and second integrated auxiliary magnets **26**, **27** are provided in a pair with the same shape, manufacture thereof becomes easy compared to a case of these two auxiliary magnets with different shapes, for example.

Second Embodiment

Next, the second embodiment of the present invention will be described with reference to FIG. **5** to FIG. **7**. Notably, for convenience of description, same configurations as the first embodiment will be given with the same reference signs as the first embodiment, and the description thereof will be omitted.

As shown in FIG. **5** to FIG. **7**, a rotor **11** includes first and second rotor cores **31**, **32**, a ring magnet **33** as a field magnet (see FIG. **6**), and a connecting magnet **34** as an integrated auxiliary magnet. Notably, arrows shown with solid lines in FIG. **5** to FIG. **7** indicate magnetized directions (oriented from S pole toward N pole) of the magnets **33**, **34**.

As shown in FIG. **5**, the first rotor core **31** has a plurality of first hook-shaped poles **31**b (seven in the embodiment) as hook-shaped poles formed on a peripheral portion of a first core base **31**a as a core base having a substantially disk shape. Each first hook-shaped pole **31**b includes a protruding portion **31**c protruded outward in a radial direction relative to the first core base **31**a, and a cog portion **31**d formed to extend in an axial direction from the protruding portion **31**c.

Circumferential end surfaces **31***e*, **31***f* of each first hook-shaped pole **31***b* are flat surfaces that extend in the radial direction (without being sloped relative to the radial direction when seen from the axial direction), and the protruding portion **31***c* has a cross-section in an axially orthogonal direction with a triangular shape. The cog portion **31***d* is formed to extend outward along the axial direction at a radially outer end portion of the protruding portion **31***c*, with a constant width in the circumferential direction. An angle in the circumferential direction of each first hook-shaped magnetic pole **31***b*, that is, an angle between the circumferential end surfaces **31***e*, **31***f* is set to be smaller than an angle of a gap between the first hook-shaped magnetic poles **31***b* that are adjacent in the circumferential direction.

As shown in FIG. **5** and FIG. **6**, the second rotor core **32** has a substantially same shape as the first rotor core **31**, and has a plurality of protruding portions **32***c* of second hook-shaped poles **32***b* as hook-shaped poles on a peripheral portion of a second core base **32***a* as a core base. The second core base **32***a* has a substantially disk shape. Each protruding portion **32***c* has a cross-section in the axially orthogonal direction with a triangular shape, and a cog portion **32***d* is formed to extend along the axial direction at a radially outer end portion thereof.

Circumferential end surfaces **32***e*, **32***f* of each second hook-shaped magnetic pole **32***b* are flat surfaces that extend in the radial direction, and the second hook-shaped magnetic pole **32***b* has a cross-section in the axially orthogonal direction with a triangular shape. An angle in the circumferential direction of each second hook-shaped magnetic pole **32***b*, that is, an angle between the circumferential end surfaces **32***e*, **32***f* is set to be smaller than an angle of a gap between the second hook-shaped magnetic poles **32***b* that are adjacent in the circumferential direction.

Further, the second rotor core **32** is assembled onto the first rotor core **31** such that the cog portions **32***d* of the second hook-shaped magnetic poles **32***b* are arranged respectively between the cog portions **31***d* of the corresponding first hook-shaped magnetic poles **31***b*, and such that the ring magnet **33** (see FIG. **6**) is arranged (sandwiched) in the axial direction between the first core base **31***a* and the second core base **32***a*. At this occasion, since the circumferential end surface **31***e* on one side of each first hook-shaped pole **31***b* is formed so as to be parallel in the axial direction with the circumferential end surface **32***f* on the other side of each second hook-shaped pole **32***b*, the gap between the respective end surfaces **31***e*, **32***f* is formed to be substantially linear in the axial direction. Further, since the circumferential end surface **31***f* on the other side of each first hook-shaped pole **31***b* is formed so as to be parallel in the axial direction with the circumferential end surface **32***e* on the one side of each second hook-shaped pole **32***b*, the gap between the respective end surfaces **31***f*, **32***e* is formed to be substantially linear in the axial direction.

As shown in FIG. **6**, the ring magnet **33** has an outer diameter set to be same as an outer diameter of each of the first and second core bases **31***a*, **32***a*, and is magnetized in the axial direction so as to cause the first hook-shaped poles **31***b* to function as first poles (N poles in the embodiment) and the second hook-shaped poles **32***b* to function as second poles (S poles in the embodiment). Accordingly, the rotor **11** of the second embodiment is a rotor with a so-called Randell type structure that uses the ring magnet **33** as the field magnet. The rotor **11** includes the first hook-shaped poles **31***b* that are the N poles and the second hook-shaped poles **32***b* that are the S poles alternately in the circumferential direction, and the number of the magnetic poles is fourteen (seven pole pairs). Notably, as the ring magnet **33**, a neodymium magnet may for example be used.

As shown in FIG. **5** to FIG. **7**, the connecting magnet **34** is configured of first and second interpolar magnet portions **34***a*, **34***b* as the interpolar magnet portions arranged between the first hook-shaped poles **31***b* and the second hook-shaped poles **32***b* in the circumferential direction, and connecting portions **34***c* that connect axially end portions of these interpolar magnet portions **34***a*, **34***b*.

As shown in FIG. **5**, each first interpolar magnet portion **34***a* is fixed to fit between the circumferential end surface **31***e* on the one side of the first hook-shaped pole **31***b* and the circumferential end surface **32***f* of the second hook-shaped pole **32***b* on the other side. Each second interpolar magnet portion **34***b* is fixed to fit between the circumferential end surface **31***f* on the other side of the first hook-shaped pole **31***b* and the circumferential end surface **32***e* of the second hook-shaped pole **32***b* on the one side.

The first and second interpolar magnet portions **34***a*, **34***b* are magnetized in the circumferential direction such that parts thereof that face the first and second hook-shaped poles **31***b*, **32***b* have the same polarities thereto (the part on the first hook-shaped pole **31***b* side has an N pole and the part on the second hook-shaped pole **32***b* has an S pole).

As shown in FIG. **5** and FIG. **6**, each connecting portion **34***c* is configured to have a plate shape configured to make contact with an axially end portion **31***g* of the first hook-shaped pole **31***b* (one end side of the rotor **11**) and an axially end portion **32***g* of the second hook-shaped pole **32***b* (the other end side of the rotor **11**). Further, the connecting portions **34***c* are formed integrally in advance with the first and second interpolar magnet portions **34***a*, **34***b* (at a stage prior to assembly) so as to connect the first and second interpolar magnet portions **34***a*, **34***b* in a manner of sandwiching the first and second hook-shaped poles **31***b*, **32***b* in the circumferential direction. At this occasion, since the connecting portions **34***c* are arranged alternately on the one end side and the other end side of the rotor **11** every void between hook-shaped poles **31***b*, **32***b* as described above, a zigzag shape is formed by the interpolar magnet portions **34***a*, **34***b* and the connecting portions **34***c* along the respective hook-shaped poles **31***b*, **32***b*.

Further, as shown in FIG. **6**, each connecting portion **34***c* is arranged with no gap between a radially inner surface **34***d* and outer circumferential surfaces **31***h*, **32***h* of the core bases **31***a*, **32***a*, that is, to make contact therewith. At this occasion, the first and second interpolar magnet portions **34***a*, **34***b* have inner surfaces with the substantially same radial length as the connecting portions **34***c*, and are similarly arranged with no gap between the inner surfaces thereof and the outer circumferential surfaces **31***h*, **32***h* of the core bases **31***a*, **32***a*, that is, in contact therewith.

In a motor **1** configured as above described, when a driving current is supplied to a segment conductor (SC) wire **8** via a power circuit in a circuit containing box **5**, a magnetic field for rotating the rotor **11** is generated in a stator **6**, and the rotor **11** is rotatably driven.

Next, operation of the motor **1** will be described.

In the rotor **11**, magnetic flux leakage between the hook-shaped poles **31***b*, **32***b* is reduced by arranging, between the first and second hook-shaped poles **31***b*, **32***b* in the circumferential direction, the interpolar magnet portions **34***a*, **34***b* that are magnetized to have the same polarity with the first and second hook-shaped poles **31***b*, **32***b* at parts facing therewith.

Here, in the above described motor **1** (rotor **11**), for example, all of the interpolar magnet portions **34***a*, **34***b* arranged between the first and second hook-shaped poles **31***b*,

32*b* in the circumferential direction are formed integrally in advance in a manner of being connected by the connecting portions **34***c*. Due to this, the number of components can be suppressed compared to a case of arranging the respective interpolar magnet portions **34***a*, **34** as separate components between the first and second hook-shaped poles **31***b*, **32***b* in the circumferential direction.

Next, advantages that are characteristic to the second embodiment will be described below.

(4) The interpolar magnet portions **34***a*, **34***b* that are magnetized to have the same polarities with the respective hook-shaped poles **31***b*, **32***b* at the parts facing therewith are provided, at least a pair of which is arranged between the corresponding first and second hook-shaped poles **31***b*, **32***b* in the circumferential direction in a manner of sandwiching at least one (all in the embodiment) of the hook-shaped poles **31***b*, **32***b* in the circumferential direction. Among the plurality of interpolar magnet portions **34***a*, **34***b*, the first and second interpolar magnet portions **34***a*, **34***b* that are arranged in a manner of sandwiching the corresponding hook-shaped poles **31***b*, **32***b* are formed integrally in advance. By thus arranging the first and second interpolar magnet portions **34***a*, **34***b*, the magnetic flux leakage that may be generated between the respective hook-shaped poles **31***b*, **32***b* can be reduced, and thereby a motor output can be improved. Further, an increase in the number of components can be suppressed by integrally forming the first and second interpolar magnet portions **34***a*, **34***b* that are arranged in the manner of sandwiching the corresponding hook-shaped poles **31***b*, **32***b*, in advance among the plurality of first and second interpolar magnet portions **34***a*, **34***b*.

(5) Since the first and second interpolar magnet portions **34***a*, **34***b* are arranged in every void between the hook-shaped poles **31***b*, **32***b*, the magnetic flux leakage from each of the hook-shaped poles **31***b*, **32***b* can further be suppressed, and the output of the motor **1** can be made higher.

(6) Since all of the first and second interpolar magnet portions **34***a*, **34***b* are formed integrally, all of the interpolar magnet portions **34***a*, **34***b* are formed as one component, by which the number of components can be suppressed.

(7) As described above, since the connecting portions **34***c* are arranged alternately on the one end side and the other end side of the rotor **11** in every void between hook-shaped poles **31***b*, **32***b*, the zigzag shape formed by the interpolar magnet portions **34***a*, **34***b* and the connecting portions **34***c* along the respective hook-shaped poles **31***b*, **32***b*, and the interpolar magnet portions can more surely be retained by the first and second rotor cores **31**, **32**.

(8) Since a rotation shaft **12** is a metal shaft made of a non-magnetic body, magnetic resistance can be made higher compared to a magnetic body, and the magnetic flux leakage that may be generated between the first and second hook-shaped poles **31***b*, **32***b* can be suppressed. As a result, the output of the motor **1** can be made higher.

The first and second embodiments of the present invention may be changed as follows.

Although in the first embodiment, the axial length of the first and second interpolar magnet portions **26***a*, **27***a*, **26***b*, **27***b* is set to be half the axial length of the first and second hook-shaped poles **21***b*, **22***b* (so as to have the same axial length as the first and second hook-shaped poles **21***b*, **22***b* in a manner of being aligned in the axial direction), the present invention is not limited hereto, and may for example be changed as shown in FIG. **8** and FIG. **9**.

That is, in this example (FIG. **8** and FIG. **9**), a first integrated auxiliary magnet **26** is configured by a first axially covering magnet portion **26***c* and first interpolar magnet portions **41** being formed integrally, and a second integrated auxiliary magnet **27** is configured by a second axially covering magnet portion **27***c* and second interpolar magnet portions **42** being integrated. Each first interpolar magnet portion **41** has a shape obtained by combining the first interpolar magnet portions **26***a*, **27***a* of the first embodiment, and an axial length thereof is set to be same as an axial length of each of first and second hook-shaped poles **21***b*, **22***b*. Further, each second interpolar magnet portion **42** has a shape obtained by combining the second interpolar magnet portions **26***b*, **27***b* of the first embodiment, and an axial length thereof is set to be same as the axial length of each of the first and second hook-shaped poles **21***b*, **22***b*. By the configuration as above described, similar advantages as of the first embodiment can also be achieved.

Although in the first embodiment, each of the first and second axially covering magnet portions **26***c*, **27***c* is formed in a simple disk shape (shape configured to cover the end surfaces of the first and second back auxiliary magnets **24**, in the axial direction), they may be formed in shapes that do not overlap with back auxiliary magnets (first and second back auxiliary magnets **24**, **25**) in the axial direction.

For example, changes may be made as shown in FIG. **10** to FIG. **12**. In this example (see FIG. **10** to FIG. **12**), notch portions **43** are formed in the first and second axially covering magnet portions **26***c*, **27***c* at parts to overlap with the first and second back auxiliary magnets **24**, **25** of the first embodiment in the axial direction (see FIG. **1** to FIG. **4**).

Further, for example, changes may be made as shown in FIG. **13** and FIG. **14**. In this example (see FIG. **13** and FIG. **14**), notch portions **44** are formed in the first and second axially covering magnet portions **26***c*, **27***c* at positions to overlap with the first and second back auxiliary magnets **24**, in the axial direction in the further example as above described (see FIG. **8** and FIG. **9**). Notably, each notch portion **44** in the first axially covering magnet portion **26***c* in this example (see FIG. **13** and FIG. **14**) is formed by additionally notching the first axially covering magnet portion **26***c* to a part corresponding to the second interpolar magnet portion **42**, and an axial length of each second interpolar magnet portion **42** is set correspondingly longer (to a length obtained by adding the axial length of the first and second hook-shaped poles **21***b*, **22***b* and a thickness of the first axially covering magnet portion **26***c*). Further, each notch portion **44** in the second axially covering magnet portion **27***c* in this example (see FIG. **13** and FIG. **14**) is formed by notching the second axially covering magnet portion **27***c* to a part corresponding to the first interpolar magnet portion **41**, and an axial length of each first interpolar magnet portion **41** is set correspondingly longer (to a length obtained by adding the axial length of the first and second hook-shaped poles **21***b*, **22***b* and a thickness of the second axially covering magnet portion **27***c*).

With such a configuration (see FIG. **10** to FIG. **14**), similar advantages as of the first embodiment can also be achieved. In addition, since the covering magnet portions (the first and second axially covering magnet portions **26***c*, **27***c*) are formed in shapes that do not overlap with the back auxiliary magnets (the first and second back auxiliary magnets **24**, **25**) in the axial direction (include the notch portions **43**, **44**), magnetic flux leakage can be reduced effectively (without unnecessarily increasing the number of magnets to be used).

Although in the first embodiment, the rotor **11** including one each of the first and second rotor cores **21**, **22** is provided, the present invention is not limited hereto. For example, as shown in FIG. **15** and FIG. **16**, a rotor **51** may include a pair each of first and second rotor cores **21**, **22**. More specifically, in this example (FIG. **15** and FIG. **16**) a pair of intermediate members W, each of which is configured by the first and second rotor cores **21**, **22**, the ring magnet **23** (see FIG. **4**), and the first and second back auxiliary magnets **24**, **25** of the first embodiment, is provided, and the pair of intermediate members W is layered symmetrically in an axial direction. Further, an axial length of each of the first and second interpolar magnet portions **41**, **42** of the further example (see FIG. **13** and FIG. **14**) is set correspondingly longer. With such a configuration, similar advantages as of the first embodiment and the further example can also be achieved.

Although in the first embodiment, the axially covering magnet portions (first and second axially covering magnet portions **26***c*, **27***c*) are configured to be provided on both end surfaces of the rotor **11** in the axial direction, the present invention is not limited hereto, and the axially covering magnet portions may be configured to be provided on only one end surface in the axial direction. In this case, the number of the integrated auxiliary magnet provided in the rotor may be one.

For example, changes may be made as shown in FIG. **17** and FIG. **18**. In this example (see FIG. **17** and FIG. **18**), only a first integrated auxiliary magnet **26** is provided, and a second integrated auxiliary magnet **27** is not provided. The first integrated auxiliary magnet **26** is configured by a first axially covering magnet portion **26***c* and first and second interpolar magnet portions **45**, **46** being formed integrally. Each first interpolar magnet portion **45** has a shape obtained by combining the first interpolar magnet portions **26***a*, **27***a* of the first embodiment, and an axial length thereof is set to be same as an axial length of each of first and second hook-shaped poles **21***b*, **22***b*. Further, each second interpolar magnet portion **46** has a shape obtained by combining the second interpolar magnet portions **26***b*, **27***b* of the first embodiment, and an axial length thereof is set to be same as the axial length of each of the first and second hook-shaped poles **21***b*, **22***b*.

Although in the first embodiment, the integrated auxiliary magnets (first and second integrated auxiliary magnets **26**, **27**) are provided in a pair with the same shape, the present invention is not limited hereto, and these two members may be made with different shapes.

Although in the first embodiment, the rotor **11** includes the back auxiliary magnets (first and second back auxiliary magnets **24**, **25**), the present invention is not limited hereto, and it may not include the back auxiliary magnets.

Although in the second embodiment, the first and second interpolar magnet portions **34***a*, **34***b* are arranged along the axial direction, for example, as shown in FIG. **19**, first and second interpolar magnet portions **34***a*, **34***b* may be arranged to intersect with the axial direction from a radial directional view (side view). In FIG. **19**, each of first and second hook-shaped poles **31***b*, **32***b* is formed with narrower width in a circumferential direction toward a distal side of the corresponding hook-shaped pole **31***d*, **32***d* as an extended portion that is extended in the axial direction. Further, each of the first and second interpolar magnet portions **34***a*, **34***b* is configured to extend along the corresponding hook-shaped pole **31***d* or **32***d* as the extended portion, by being inclined toward a side of each of the hook-shaped poles that is sandwiched in the circumferential direction by the magnet portions that sandwich the hook-shaped poles in the circumferential direction. Here, since the interpolar magnet portions **34***a*, **34***b* that sandwich the hook-shaped poles **31***b*, **32***b* in the circumferential direction are formed to extend along the extended portions when assembling the first and second hook-shaped poles **31***b*, **32***b* of the respective rotor cores **31**, **32** to be arranged alternately in the circumferential direction, by being inclined toward the sides of the hook-shaped poles **31***b*, **32***b*, the assembly upon sandwiching the ring magnet **33** can be made easier by moving the hook-shaped poles **31***b*, **32***b* closer thereto in the axial direction.

Although in the second embodiment, the inner surfaces **34***d* of the connecting portions **34***c* are configured to make contact with the outer circumferential surfaces **31***h*, **32***h* of the first and second core bases **31***a*, **32***a*, the present invention is not limited hereto, and for example, as shown in FIG. **20**, a configuration in which a gap K is provided between the respective inner surfaces **34***d* and each of the outer circumferential surfaces **31***h*, **32***h*. For example, the gaps K may be provided by forming a concave shape on an inside in a radial direction of each outer circumferential surface **31***h* of the first core base **31***a* (see FIG. **20**), and forming a concave shape on an inside in the radial direction of each outer circumferential surface **32***h* of the second core base **32***a* (not shown in FIG. **20**). By thus providing the gaps K, magnetic flux is prevented from leaking in toward the inside of the rotor **11** in the radial direction.

In the first embodiment, two or more first and second interpolar magnet portions **26***a*, **26***b* are formed integrally on axial end sides thereof by the first axially covering magnet portion **26***c*, and two or more first and second interpolar magnet portions **27***a*, **27***b* are formed integrally on axial end sides thereof by the second axially covering magnet portion **27***c*. However, the present invention is not limited hereto, and the first and second interpolar magnet portions **26***a*, **27***a*, **26***b*, **27***b* may be formed integrally at predetermined positions (for example, intermediate part of the magnet portions in the axial direction) other than the axial end sides. Further, although in the second embodiment, two or more first and second interpolar magnet portions **34***a*, **34***b* are formed integrally on an axial end sides thereof by the connecting portions **34***c*, the present invention is not limited hereto, and first and second interpolar magnet portions **34***a*, **34***b* may be formed integrally at predetermined positions (for example, intermediate part in of the magnet portions the axial direction) other than the axial end sides.

In the first and second embodiments, a single ring magnet **33** is used as the field magnet, a configuration in which a permanent magnet that is divided into a plurality of pieces may be arranged around a rotation shaft **12** in between the first and second core bases **31***a*, **32***a* in the axial direction.

Although not specifically mentioned in the first and second embodiments, the first and second rotor cores **31**, **32** and armature cores **7** may be configured for example by stacking magnetic metal plate materials or forming magnetic powder materials.

In the first and second embodiments, for example, the first and second interpolar magnet portions **26***a*, **27***a*, **26***b*, **27***b*, **34***a*, **34***b* may be formed integrally by performing two-color molding. In this case, an increase in the number of components can be suppressed.

In the first embodiment, the number of poles of the rotor **11** is ten, and in the second embodiment, the number of the poles of the rotor **11** is fourteen. However, the number of the poles can suitably be changed.

Although types of the integrated auxiliary magnets are not specifically mentioned in the first and second embodiments, for example, bonded magnets (plastic magnets, rubber magnets, and the like), sintered magnets, or a combination thereof may be used. For example, in the first embodiment, the sintered magnets may be used for the interpolar magnet portions (the first and second interpolar magnet portions **26***a*, **27***a*, **26***b*, **27***b*, **34***a*, **34***b*), and the bonded magnets may be used for the axially covering magnet portions (the first and second axially covering magnet portions **26***c*, **27***c*). Further, as for a composition (material) of the integrated auxiliary magnets, for example, ferrite systems, SmFeN systems, nitriding iron systems, or Neodymium systems, or a combination thereof may suitably be employed. According to this, an output adjustment of the motor can be performed.

Third Embodiment

A third embodiment of the present invention will be described below in accordance with the drawings.

As shown in FIG. **21** and FIG. **22**, a rotor **111** includes a first and second rotor cores **121**, **122**, a ring magnet **123** (see FIG. **23**) and an auxiliary magnet **124**. Notably, arrows shown with solid lines in FIG. **22** and FIG. **23** indicate magnetized directions (oriented from S pole toward N pole) of the respective magnets **123**, **124**.

The first and second rotor cores **121**, **122** and the ring magnet **123** of the third embodiment are shown in FIG. **21** and FIG. **22**. Descriptions for configurations similar to the first and second rotor cores **21**, **22** and the ring magnet **23** of the first embodiment will be omitted.

The rotor **111** of the third embodiment is a rotor with a so-called Randell type structure that uses the ring magnet **123** as a field magnet. The rotor **111** includes first hook-shaped poles **121***b* that are the N poles and second hook-shaped poles **122***b* that are the S poles alternately in a circumferential direction, and a number of poles is ten (five pole pairs). Here, since the number of pole pairs is an odd number of three or more, a shape that is stable against magnetic vibration can be provided by the configuration of hook-shaped poles with same polarity not facing one another in the circumferential direction by 180 degrees when seen with respect to rotor core by itself.

As shown in FIG. **23**, the auxiliary magnet **124** includes a plurality of circumferentially divided portions **125**, **126** that is divided in the circumferential direction, and is configured by consecutively and adjacently arranging these circumferentially divided portions **125**, **126**. The circumferentially divided portions **125**, **126** include the first circumferentially divided portions **125** to be attached to the first hook-shaped poles **121***b* and the second circumferentially divided portion **126** to be attached to the second hook-shaped poles **122***b*.

Each first circumferentially divided portion **125** to be attached to the respective first hook-shaped poles **121***b* is formed to have a C-shape in an axial directional view as shown in FIG. **23**, and includes a first back magnet portion **125***a* and first interpolar magnet portions **125***b*.

As shown in FIG. **21** to FIG. **23**, each first back magnet portion **125***a* is arranged between a back surface **121***e* of the first hook-shaped pole **121***b* (an inner surface in a radial direction) and an outer circumferential surface **122***f* of the second core base **122***a*. Each first back magnet portion **125***a* has a cross-section in an axially orthogonal direction with a triangular shape, and is magnetized so as to cause a side in contact with the back surface **121***e* of the first hook-shaped pole **121***b* to be the N pole similar to the first hook-shaped pole **121***b*, and a side in contact with the outer circumferential surface **122***f* of the second core base **122***a* to be the S pole similar to the second core base **122***a*. Further, the first back magnet portions **125***a* may be configured for example of ferrite magnets.

As shown in FIG. **21** and FIG. **23**, the first interpolar magnet portions **125***b* are formed integrally with the corresponding first back magnet portion **125***a* so as to extend outward in the radial direction from both sides in the circumferential direction of the first back magnet portion **125***a*, and so as to be positioned on both sides in the circumferential direction of the first hook-shaped poles **121***b*. Further, the first interpolar magnet portions **125***b* on both sides in the circumferential direction of each first hook-shaped pole **121***b* are configured to have half a circumferential thickness (length) of a gap between the first hook-shaped pole **121***b* and the second hook-shaped pole **122***b* in the circumferential direction.

Each second circumferentially divided portion **126** to be attached to the respective second hook-shaped poles **122***b* is formed to have a C-shape in the axial directional view, as shown in FIG. **23**, similar to the first circumferentially divided portions **125** on a first hook-shaped pole **121***b* side, and includes a second back magnet portion **126***a* and second interpolar magnet portions **126***b*.

As shown in FIG. **21** to FIG. **23**, each second back magnet portion **126***a* is arranged between a back surface **122***e* of the second hook-shaped pole **122***b* (an inner surface in the radial direction) and an outer circumferential surface **121***f* of the first core base **121***a*. Each second back magnet portion **126***a* has a cross-section in the axially orthogonal direction with a triangular shape, and is magnetized so as to cause a side in contact with the back surface **122***e* of the second hook-shaped pole **122***b* to be the S pole, and a side in contact with the outer circumferential surface **121***f* of the first core base **121***a* to be the N pole. Further, the second back magnet portions **126***a* may be configured of ferrite magnets, for example, similar to the first back magnet portions **125***a*.

Here, lengths of the first back magnet portions **125***a* and the second back magnet portions **126***a* in the axial direction are set such that they overlap one another in the axial direction at a position in the axial direction of the rotor **111** in which the ring magnet **123** is to be arranged; in other words, such that they extend from both surfaces of the rotor **111** to the position in the axial direction where the ring magnet **123** is arranged.

The second back magnet portions **126***a* have substantially same shape as the first interpolar magnet portions **125***b*, and are formed integrally with the corresponding second back magnet portion **126***a* so as to extend outward in the radial direction from both sides in the circumferential direction of the second back magnet portion **126***a*, and so as to be positioned on both sides in the circumferential direction of the second hook-shaped poles **122***b*. Further, the second interpolar magnet portions **126***b* on both sides in the circumferential direction of each second hook-shaped pole **122***b* are configured to have half the circumferential thickness (length) of the gap between the first hook-shaped pole **121***b* and the second hook-shaped pole **122***b* in the circumferential direction. That is, each interpolar magnet between the first hook-shaped poles **121***b* and the second hook-shaped poles **122***b* is formed by combining both the first interpolar magnet portion **125***b* of the first circumferentially divided portion **125** and the second interpolar magnet portion **126***b* of the second circumferentially divided portion **126**. Further, as shown in FIG. **22**, the respective interpolar magnet portions **125***b*, **126***b* of the respective circumferentially divided portions **125**, **126** are arranged to be annular, by making contact with each other in the circumferential direction at a substantially center position in the circumferential direction between the first hook-shaped poles **121***b* and the second hook-shaped poles **122***b*.

A motor **101** is configured as above described, and when a three-phase driving current is supplied to a segment conductor (SC) wire **108** via a power circuit in a circuit containing box **105**, a magnetic field for rotating the rotor **111** is generated in a stator **106**, and the rotor **111** is rotatably driven.

Next, the operation of the motor **101** will be described.

The rotor **111** of the motor **101** of the embodiment includes the auxiliary magnet **124** including the circumferentially divided portions **125**, **126** that are configured by the interpolar magnet portions **125**_b_, **126**_b_ arranged between the respective hook-shaped poles **121**_b_, **122**_b_ in the circumferential direction, and the back magnet portions **125**_a_, **126**_a_ arranged at the back surfaces of the first and second hook-shaped poles **121**_b_, **122**_b_, the interpolar magnet portions **125**_b_, **126**_b_ and the back magnet portions **125**_a_, **126**_a_ being formed integrally. Accordingly, by configuring the auxiliary magnet **124** by the interpolar magnet portions **125**_b_, **126**_b_ and the back magnet portions **125**_a_, **126**_a_, magnetic flux leakage from the gaps is suppressed, and contribution to high output of the rotor is thereby achieved. Further, since the circumferentially divided portions **125**, **126** of the auxiliary magnet **124** are configured by the respective interpolar magnet portions **125**_b_, **126**_b_ and the back magnet portions **125**_a_, **126**_a_ formed integrally, the number of components can be suppressed.

Next, the advantages that are characteristic to the third embodiment will be described below.

(9) The rotor **111** of the third embodiment includes the auxiliary magnet **124**. The auxiliary magnet **124** is configured by formed integrally the interpolar magnet portions **125**_b_, **126**_b_ arranged between the first hook-shaped poles **121**_b_ and the second hook-shaped poles **122**_b_ in the circumferential direction, and the back magnet portions **125**_a_, **126**_a_ arranged at the back surfaces of the first and second hook-shaped poles **121**_b_, **122**_b_, and contacts the respective hook-shaped poles **121**_b_, **122**_b_ in the radial direction and in the circumferential direction. Accordingly, the magnetic flux leakage can be suppressed with a reduced number of components by providing the auxiliary magnet **124** formed by integrating the interpolar magnet portions **125**_b_, **126**_b_ and the back magnet portions **125**_a_, **126**_a_.

(10) The auxiliary magnet **124** has a magnetized direction in the same direction as the respective hook-shaped poles **121**_b_, **122**_b_ that function as first and second poles due to the ring magnet **123** as the field magnet. Due to this, magnetic flux at outer surfaces of the hook-shaped poles **121**_b_, **122**_b_ can be increased.

(11) The auxiliary magnet **124** is configured by arranging the plurality of circumferentially divided portions **125**, **126**, which is divided in the circumferential direction, consecutively and adjacently in the circumferential direction, and each of the circumferentially divided portions **125**, **126** respectively includes the back magnet portions **125**_a_, **126**_a_ and the interpolar magnet portions **125**_b_, **126**_b_. Accordingly, the interpolar magnet portions **125**_b_, **126**_b_ can be prevented from getting out of place by centrifugal force upon the rotation of the rotor by integrating with the back magnet portions **125**_a_, **126**_a_ being integrated. Further, since the auxiliary magnet **124** is formed by arranging the circumferentially divided portions **125**, **126**, which are divided in advance in the circumferential direction, to be annular and adjacent to one another, the circumferentially divided portions **125**, **126** can be formed without using a high-precision forming device compared to a case of a circular ring-shaped auxiliary magnet **124** formed integrally in advance.

(12) In each of the circumferentially divided portions **125**, **126**, the respective interpolar magnet portions **125**_b_, **126**_b_ are adjacent to the interpolar magnet portions **125**_b_, **126**_b_ of other circumferentially divided portions **125**, **126**. That is, since the circumferentially divided portions **125**, **126** of the auxiliary magnet **124** are divided between the interpolar magnet portions **125**_b_, **126**_b_, the back magnet portions **125**_a_, **126**_a_ of the circumferentially divided portions **125**, **126** can be covered by the hook-shaped poles. Due to this, separation of the interpolar magnet portions **125**_b_, **126**_b_ can be suppressed.

The third embodiment may be changed as follows.

Although in the third embodiment, the circumferentially divided portions **125**, **126** are formed separately, the back magnet portions and the interpolar magnet portions may be formed integrally (formed integrally) to be annular. For example, as shown in FIG. **28**, the circumferentially divided portions **125**, **126** that make contact with the respective hook-shaped poles **121**_b_, **122**_b_ may be configured integrally to be annular. By the configuration as above described, a number of components can further be suppressed.

Although not specifically mentioned in the third embodiment, as shown in FIG. **29**, the circumferentially divided portions **125**, **126** as auxiliary magnets may be configured by anisotropic magnets (polar anisotropic magnets), each of which has magnetic flux oriented in a specific direction. By the configuration as above described, the strong magnetic flux toward a specific direction caused by the anisotropic magnets can be generated at the respective hook-shaped poles. Thus, a torque in the rotor is effectively ensured.

Fourth Embodiment

Next, the fourth embodiment of the present invention will be described below in accordance with the drawings. The fourth embodiment differs in a configuration of an auxiliary magnet from the third embodiment, which will mainly be described. Further, same reference signs will be given to same members as the third embodiment, and a part or an entirety of description thereof will be omitted.

As shown in FIG. **24**, an auxiliary magnet **131** includes a plurality of circumferentially divided portions **132** that is divided into a number of pole pairs (five in the embodiment) at substantially equal angles in a circumferential direction, and is configured by arranging these circumferentially divided portions **132** consecutively and adjacently in the circumferential direction one another. Further, the auxiliary magnet **131** may be formed by a sintered magnet or a bonded magnet, and a SmFeN magnet, a ferrite magnet, or a neodymium magnet may be employed.

As shown in FIG. **25**, each circumferentially divided portion **132** includes two interpolar magnet portions **132**_a_, two side back magnet portions **132**_b_ that are positioned on outer sides than the interpolar magnet portions **132**_a_ in the circumferential direction, and a central back magnet portion **132**_c_ that is positioned between the interpolar magnet portions **132**_a_.

The interpolar magnet portions **132**_a_ are positioned between the first hook-shaped poles **121**_b_ and the second hook-shaped poles **122**_b_ in the circumferential direction, each of which has a configuration in which the first interpolar magnet portion **125**_b_ and the second interpolar magnet portion **126**_b_ of the third embodiment, which make contact with each other in the circumferential direction, are formed integrally. That is, each interpolar magnet portion **132**_a_ is configured to have a same circumferential thickness (length) as a gap between the first hook-shaped pole **121**_b_ and the second hook-shaped pole **122**_b_ in the circumferential direction.

The central back magnet portion **132**_c_ corresponds to the second back magnet portion **126**_a_ in the third embodiment, and is arranged between a back surface **122**_e_ of the second hook-shaped pole **122**_b_ and an outer circumferential surface **121**_f_ of a first core base **121**_a_. The central back magnet portion **132**_c_ has a cross-section in an axially orthogonal direction with a triangular shape.

As shown in FIG. **24** and FIG. **25**, the two side back magnet portions **132***b* correspond to the first back magnet portions **125***a* in the third embodiment, each of which is arranged between a back surface **121***e* of the first hook-shaped pole **121***b* and an outer circumferential surface **122***f* of the second core base **122***a*. Further, each of the two side back magnet portions **132***b* of the circumferentially dividing portions **132** is configured to have half a circumferential thickness (length) of a circumferential width of the first hook-shaped pole **121***b* or the second hook-shaped pole **122***b*. Notably, a combination of the two side back magnet portions **132***b* that contact with one another in the circumferential direction corresponds to the first back magnet portion **125***a* of the third embodiment. Further, as shown in FIG. **24**, the two side back magnet portions **32***b* of the circumferentially divided portions **132** contact with one another in the circumferential direction at a substantially center position of a back surface of the first hook-shaped pole **121***b*. The plurality of circumferentially divided portions **132** is arranged to be annular.

Next, the operation of the fourth embodiment will be described.

The auxiliary magnet **131** of the fourth embodiment has the circumferentially divided portions **132** divided into the number of pole pairs at equal angles in the circumferential direction. Due to this, each circumferentially divided portion **132** make contact with the hook-shaped pole of the first rotor core or the hook-shaped pole of the second rotor core in the radial direction, and is retained by the corresponding hook-shaped pole **21***b*, **22***b*.

Further, in a pair of the adjacent circumferentially divided portions **132**, two side back magnet portions **132***b* are adjacent (make contact) with each other in the circumferential direction. Due to this, compared to a case in which the two adjacent side back magnet portions **132***b* are formed integrally, a small gap may be generated between the two adjacent side back magnet portions **132***b*. However, the two side back magnet portions **132***b* are magnetized in the radial direction as a whole, so the gap is prevented from becoming a magnetic resistance.

Next, advantages that are characteristic to the fourth embodiment will be described below.

(13) Each circumferentially divided portion **132** is inevitably retained by the hook-shaped pole **121***b* of the first rotor core **121** or the hook-shaped pole **122***b* of the second rotor core **122** by the circumferentially divided portions **132** being divided into the number of pole pairs at the equal angles in the circumferential direction, whereby the circumferentially divided portions **132** (auxiliary magnet **131**) are prevented from getting out from the rotor cores **121**, **122** upon rotation of the rotor.

(14) In each circumferentially divided portion **132**, the two side back magnet portions **132***b* respectively are adjacent to the two side back magnet portions **132***b* of other circumferentially divided portions **132**. Thus, the dividing positions between the adjacent circumferentially divided portions **132** correspond to the back surfaces of the hook-shaped poles **121***b*, **122***b*. Since the two side back magnet portions **132***b* are magnetized in the radial direction as a whole, the dividing positions between the adjacent circumferentially divided portions **132** can be prevented from becoming the magnetic resistances. Due to this, contribution to higher output of the motor can be made.

The fourth embodiment may be changed as follows.

Although not specifically mentioned in the fourth embodiment, as shown in FIG. **26** and FIG. **27** for example, a ring magnet **123** as a field magnet may be integrated in a radial direction with circumferentially divided portions **132** (auxiliary magnet **135**). In the case of integrating with the respective circumferentially divided portions **132**, sectorial-shaped magnets **123***a* into which the ring magnet **123** is divided in a circumferential direction may be integrated with the circumferentially divided portions **132**, and may be arranged to be annular in the circumferential direction. With the configuration as above described, the auxiliary magnet **135** is integrated with the ring magnet **123** in the radial direction. Thus, the number of components can further be suppressed. Further, getting out of the interpolar magnet portions **132***a* upon rotating the rotor can more surely be prevented.

Fifth Embodiment

Next, the fifth embodiment of the present invention will be described below in accordance with the drawings. The fifth embodiment differs in a configuration of an auxiliary magnet from the third embodiment, which will mainly be described. Further, same reference signs will be given to same members as the third embodiment or the fourth embodiment, and a part or an entirety of description thereof will be omitted.

As shown in FIG. **30**, an auxiliary magnet **141** is formed integrally to be annular, and includes an anisotropic magnet portion **142** and different property portions **143** that have a different magnetic property from that of the anisotropic magnet portion **142**.

The anisotropic magnet portion **142** is configured of a polar anisotropic magnet having a polar anisotropic orientation. The anisotropic magnet portion **142** is annular and includes back magnet portions **142***a* and interpolar magnet portions **142***b*.

As shown in FIG. **30**, each back magnet portion **142***a* has a slit portion **42***c* that is positioned at a substantially center in a circumferential direction and forms a concave shape inwardly in a radial direction. Each slit portion **142***c* of the fifth embodiment is formed at a polar center (circumferential center of the pole) of the anisotropic magnet portion **142**. Further, each slit portion **142***c* is formed to have a radial length that is half or more of a radial length of each back magnet portion **142***a*.

As shown in FIG. **30**, in the slit portions **142***c* the different property portions **143** are arranged. The different property portions **143** have the different magnetic property from that of the anisotropic magnet portion **142**, and thereby a different coefficient of contraction from that of the anisotropic magnet portion **142**. As the different property portions **143**, in the fifth embodiment, for example, isotropic magnets may be employed.

Next, the operation of the fifth embodiment will be described.

In addition to the substantially annular anisotropic magnet portion **142**, the auxiliary magnet **141** of the fifth embodiment includes the different property portions **143** having the different magnetic property (coefficient of contraction) from that of the anisotropic magnet portion **142**. Here, in the anisotropic magnet portion **142**, the coefficient of contraction differs upon sintering and firing between a part having a crystal orientation that is prone to magnetization (easily magnetized axial direction) and a part having a crystal orientation that is less prone to the magnetization (hardly magnetized axial direction). Due to this, by using the anisotropic magnet portion at a part of the annular auxiliary magnet, internal stress may be accumulated, and the auxiliary magnet might break. Thus, with the different property portions **143** having the different coefficient of contraction as aforementioned, it is possible to absorb the difference in the coefficients of contraction between the part having the easily magnetized axial direction and the part having the hardly magnetized direction of the anisotropic magnet portion **142**.

Next, advantages that are characteristic to the fifth embodiment will be described below.

(15) The auxiliary magnet **141** is formed integrally to be annular, and includes the anisotropic magnet portion **142** and the different property portions that have the different magnetic property from that of the anisotropic magnet portion. Here, the coefficient of contraction differs upon sintering and firing between the part having the crystal orientation that is prone to the magnetization (easily magnetized axial direction) and the part having the crystal orientation that is less prone to the magnetization (hardly magnetized axial direction) in the anisotropic magnet portion **142**. Due to this, by using the anisotropic magnet portion **142** at a part of the annular auxiliary magnet **141**, internal stress may be accumulated and the auxiliary magnet **141** might break. Due to this, by providing the auxiliary magnet **141** with the different property portions **143** having the different magnetic property from that of the anisotropic magnet portion **142**, the concentration of the internal stress can be reduced by using the difference in the coefficient of contraction between the different property portions **143** and the anisotropic magnet portion **142**, and the breakage of the auxiliary magnet **141** can be prevented.

(16) By employing the isotropic magnets as the different property portions **143** of the auxiliary magnet **141**, the internal stress of the auxiliary magnet **141** is alleviated to prevent the occurrence of the breakage, and magnetic force (magnetic flux concentration) to be generated can be increased compared to a case of providing gaps instead of the different property portions **143**.

(17) Since the different property portions **143** of the auxiliary magnet **141** are provided at an inner side of the auxiliary magnet **141** in the radial direction, not providing gaps on the outer side in the radial direction instead of the different property portions **143**, change in the shape on an outer side in the radial direction can be prevented.

(18) Since the anisotropic magnet portion **142** is configured of the polar anisotropic magnet, a maximum magnetic flux concentration can be made high compared to a radially oriented anisotropic magnet.

The fifth embodiment may be changed as follows.

In the fifth embodiment, the radial length of the slit portions **142***c* is set to be half or more of the radial length of the back magnet portions **142***a*, and the radial length of the different property portions **143** is set to be same as the slit portions **142***c*. However, the present invention is not limited hereto. For example, as shown in FIG. **31**, radial lengths of slit portions **142***c* and different property portions **143** may be set to be half or less of a radial length of back magnet portions **142***a*.

In the fifth embodiment, the different property portions **143** are provided at the circumferential center (polar center) of the back magnet portions **142***a*. However, a configuration in which different property portions **143** are provided in interpolar magnet portions **142***b* as shown in FIG. **32** may be employed.

Although in the fifth embodiment, the back magnet portions **142***a* and the interpolar magnet portions **142***b* are formed integrally to configure the anisotropic magnet portion **142**, the present invention is not limited hereto. For example, as shown in FIG. **33**, the back magnet portions **142***a* and the interpolar magnet portions **142***b* may be formed separately. Further, in this case, the anisotropic magnet portion **142** may not be a polar anisotropic magnet, and the back magnet portions **142***a* may be configured of radially oriented anisotropic magnets, and the interpolar magnet portions **142***b* may be configured of isotropic magnets as different property portions. Further, in FIG. **33**, gaps **145** as different property portions are formed on an outer side in a radial direction of interpolar magnet portions **142***b*.

Although in the fifth embodiment, the different property portions **143** are configured by the isotropic magnets, gaps **146** may be employed as the different property portions as shown in FIGS. **34**A, **34**B. With such a configuration, the internal stress of the auxiliary magnet can more surely be alleviated by the gaps **146**, and the occurrence of the breakage can further be prevented.

Sixth Embodiment

Next, the sixth embodiment of the present invention will be described below in accordance with the drawings. Notably, same reference signs will be given to same members as the third embodiment, and a part or an entirety of description thereof will be omitted.

As shown in FIG. **35**, the auxiliary magnet **151** includes a plurality of axially divided portions **152** to **154** that is divided in an axial direction, and is configured by arranging these axially divided portions **152** to **154** consecutively and adjacently in the axial direction. The axially divided portions **152** to **154** are obtained by dividing the auxiliary magnet **151** into three in the axial direction, and include a central divided portion **152** at a center in the axial direction, and two side divided portions **153**, **154** on both sides of the central divided portion **152** in the axial direction.

Respective divided portions **152** to **154** include interpolar magnet portions **152***a*, **153***a*, **154***a*, and back magnet portions **152***b*, **153***b*, **154***b*.

As shown in FIG. **35**, the two side divided portions **153**, **154** include circumferentially divided bodies **155** of the same number as of pole pairs, where in each of the circumferentially divided bodies **155**, one back magnet portion **153***b*, **154***b* and interpolar magnet portions **153***a*, **154***a* extending outward in the radial direction from circumferentially both sides of the corresponding back magnet portion **153***b*, **154***b* are formed integrally.

As shown in FIG. **35**, the central divided portion **152** has interpolar magnet portions **152***a* of the same number as of pole pairs and back magnet portions **152***b* formed integrally. Further, the central divided portion **152** is formed integrally with a ring magnet **123** as a field magnet in the third embodiment.

Next, the operation of the sixth embodiment will be described.

The auxiliary magnet **151** of the sixth embodiment is configured by arranging the plurality of axially divided portions **152** to **154** that is divided in the axial direction consecutively and adjacently in the axial direction. The respective divided portions **152** to **154** include the interpolar magnet portions **152***a*, **153***a*, **154***a*, and the back magnet portions **152***b*, **153***b*, **154***b*. With such a configuration, generation of gaps and the like in the circumferential direction is suppressed compared to a case of dividing the auxiliary magnet **151** in the circumferential direction, and the interpolar magnet portions **152***a*, **153***a*, **154***a*, and the back magnet portions **152***b*, **153***b*, **154***b* of the axially divided portions **152** to **154** are prevented from becoming magnetic resistances.

Next, advantages that are characteristic to the sixth embodiment will be described below.

(19) The auxiliary magnet **151** is configured by arranging the plurality of axially divided portions **152** to **154** that is divided in the axial direction, consecutively and adjacently in

the axial direction, and the axially divided portions **152** to **154** respectively includes the back magnet portions **152***b*, **153***b*, **154***b* and the interpolar magnet portions **152***a*, **153***a*, **154***a*. By dividing in the axial direction as above described the interpolar magnet portions **152***a*, **153***a*, **154***a* and the back magnet portions **152***b*, **153***b*, **154***b* are prevented from becoming the magnetic resistances.

(20) The axially divided portions **152** to **154** have the central divided portion **152** that is the axially divided portion at the center in the axial direction, which is integrated with the ring magnet **123** as a field magnet.

Accordingly, the number of components can be suppressed by integrating the central divided portion **152** with the ring magnet **123**.

The sixth embodiment may be changed as follows.

Although in the sixth embodiment, the auxiliary magnet **151** is configured by the axially divided portions **152** to **154** obtained by dividing the auxiliary magnet **151** into three in the axial direction, the present invention is not limited hereto. For example, as shown in FIG. **36**, the auxiliary magnet **151** may be configured by arranging axially divided portions **156**, **157** that are divided into two in the axial direction, consecutively and adjacently in the axial direction. Specifically, the axially divided portions **156**, **157** of the auxiliary magnet **151** include interpolar magnet portions **156***a*, **157***a*, and back magnet portions **156***b*, **157***b*. The interpolar magnet portions **156***a*, **157***a* and the back magnet portions **156***b*, **157***b* of the axially divided portions **156**, **157** are formed integrally to be annular respectively at their corresponding axially divided portions **156**, **157**. With such a configuration, the axially divided portions **156**, **157** come to have an identical shape. Further, in mold-forming such axially divided portions **156**, **157** that are divided into two, mold-shaping of a mold can be made easy. The axially divided portions **156**, **157** can be formed by one type of mold. Further, a divided body **123***b* obtained by dividing the ring magnet **123** of the third embodiment in the axial direction may be formed integrally with each of the axially divided portions **156**, **157**. Accordingly, the number of components can be suppressed by integration of the axially divided portions **156**, **157** with the ring magnet **123**.

Further, the third to sixth embodiments may be changed as follows.

Although in the third to sixth embodiments, a single ring magnet **123** is used as the field magnet, a configuration in which permanent magnets that are divided into a plurality of pieces are arranged around a rotary shaft **112** between the first and second core bases **121***a*, **122***a* in the axial direction may be employed.

Although not specifically mentioned in the third to sixth embodiments, the first and second rotor cores **121**, **122** and an armature core **107** may be configured by stacking magnetic metal plate materials, or molding magnetic powder materials, for example.

Although a method of winding a wire to each of teeth of a stator **106** is not specifically mentioned in the third to sixth embodiments, it may be wound by concentrated winding, or distributed winding.

Seventh Embodiment

A seventh embodiment of a rotor and a motor in which the present invention is embodied will be described below with reference to FIG. **37** to FIG. **40**.

As shown in FIG. **37**, a motor (armature) **201** includes a stator **202** that is a fixed side of the motor **201**, and a rotor **203** that is a rotary side of the motor **201** and is provided inside the stator **202** to be rotatable relative thereto. Further, when current flows in wires wound around an iron core of the stator **202**, the rotor **203** rotates relative to the stator **202** by a magnetic field generated in a magnetic field system (permanent magnet field system) between the stator **202** and the rotor **203**.

As shown in FIG. **38**, in the Randell-type rotor **203** with the magnetic field system in the seventh embodiment, for example a pair of first rotor core **204** and second rotor core **205**, and a connecting magnet (permanent magnet) **206** as an auxiliary magnet sandwiched between the pair of rotor cores **204**, **205** are provided. The connecting magnet **206** is a magnet for providing N pole/S pole properties to the respective rotor cores **204**, **205**. In a case of the seventh embodiment, an upper side in FIG. **38** is the first rotor core **204**, and a lower side is the second rotor core **205**. A non-magnetic rotation shaft (shaft) **207**, which is a rotation shaft of the rotor **203**, is attached to an axial center of the rotor **203**. Each of the rotor cores **204**, **205** is press-fixed to fit to the rotation shaft **207**.

As shown in FIG. **38** to FIG. **40**, a plurality of hook-shaped poles **209**, **209**, . . . is provided along a circumferential direction at equal intervals to protrude outwardly in a radial pattern at a circumferential edge of a first core base **208** having a substantially disk shape in the first rotor core **204**. Further, each hook-shaped pole **209** of the first rotor core **204** has a shape of being extended out along an axial direction of a motor, that is, a shape protruding toward the lower side in FIG. **38** and FIG. **39**, and an interval between the adjacent hook-shaped poles **209**, **209** is a notch portion **210**. The second rotor core **205** has a substantially same shape as the first rotor core **204**, and similar to the first rotor core **204**, it includes a second core base **211**, hook-shaped poles **212**, and notch portions **213**. The first rotor core **204** and the second rotor core **205** are assembled in an upside-down state with each other such that the hook-shaped poles **209** (**212**) on one side meshes into the notch portions **213** (**210**) on the other side. Due to this, the hook-shaped poles **209** of the first rotor core **204** and the hook-shaped poles **212** of the second rotor core **205** are arranged alternately in the circumferential direction of the rotor. Through holes **214**, **215** for passing the rotation shaft **207** are respectively formed at centers of the respective rotor cores **204**, **205**.

The hook-shaped poles **209** (**212**) are formed with a rectangular shape as seen from a radial direction of the rotor. The hook-shaped poles **209** (**212**) may for example be formed with a square shape, or a parallelepiped shape. Further, a gap between a core base **208** and each hook-shaped pole **209** (**212**) is formed to have a cross-section with a rectangular shape. Further, the adjacent hook-shaped poles **209**, **212** are separated to provide a rectangular void as seen from the radial direction of the rotor.

The connecting magnet **206** has a shape that fills in between the first rotor core **204** and the second rotor core **205**. Specifically, the connecting magnet **206** of the seventh embodiment is configured of a magnet main body portion **216** that fills in between the core base **208** of the first rotor core **204** and a core base **211** of the second rotor core **205**, a plurality of interpolar magnet portions **217** that fills gaps between the first hook-shaped poles **209** of the first rotor core **204** and the second hook-shaped poles **212** of the second rotor core **205**, and back magnet portions **218** that fills gaps at the back surfaces of the respective hook-shaped poles **209**, **212**. Thus, the connecting magnet **206** of the seventh embodiment is an integrated connecting magnet (integrated permanent magnet) **206** as an integrated auxiliary magnet, in which the magnet main body portion **216**, the interpolar magnet portions **217**, and the back magnet portions **218** are formed integrally.

A total of ten interpolar magnet portions **217** are formed at equal intervals in the circumferential direction around the magnet main body portion **216** having the substantially disk shape so as to correspond to ten gaps in the circumferential direction that are formed between the first hook-shaped poles **209** and the second hook-shaped poles **212**. A total of ten back magnet portions **218** are formed in the circumferential direction so as to connect the adjacent interpolar magnet portions **217**. Further, a through hole **219** for passing the rotation shaft **207** is formed through the center of the magnet main body portion **216**.

As shown in FIG. **39** and FIG. **40**, the integrated connecting magnet **206** of the seventh embodiment is magnetized such that the first rotor core **204** is the N pole and the second rotor core **205** is the S pole. Specifically, the integrated connecting magnet **206** is magnetized in the axial direction of the rotor (oriented from the second rotor core **205** toward the first rotor core **204**) at the magnet main body portion **216**; is magnetized in the circumferential direction of the rotor (oriented from the second rotor core **205** toward the first rotor core **204**) at the interpolar magnet portions **217**; and is magnetized in the radial direction of the rotor (oriented from the second rotor core **205** toward the first rotor core **204**) at the back magnet portions **218**. Thus, as shown in FIG. **39** and FIG. **40**, magnetic moment in a direction of an arrow M**1** is produced in the magnet main body portion **216**, magnetic moment in a direction of an arrow M**2** is produced in the interpolar magnet portions **217**, and magnetic moment in a direction of an arrow M**3** is produced in the back magnet portions **218**.

The connecting magnet **206** of the seventh embodiment is configured of a sintered magnet, a bonded magnet (plastic magnet, rubber magnet, and the like), for example. Further, other than the above, for example, a ferrite magnet, a samarium-iron-nitrogen (Sm—Fe—N) magnet, a samarium-cobalt magnet, a neodymium magnet, an Al—Ni—Co magnet and the like may be used.

Next, the operation of the motor **201** of the seventh embodiment will be described with reference to FIGS. **39** and **40**.

As shown in FIG. **39** and FIG. **40**, the integrated connecting magnet **206** of the seventh embodiment, the magnet main body portion **216** is magnetized in the orientation of the magnetic moment in a direction of the arrow M**1**, the interpolar magnet portions **217** are magnetized in the orientation of the magnetic moment in a direction of the arrow M**2**, and the back magnet portions **218** are magnetized in the orientation of the magnetic moment in a direction of the arrow M**3**. Due to this, the first rotor core **204** becomes the N pole and the second rotor core **205** becomes the S pole. Thus, as shown in FIG. **40**, magnetic flux loops indicated by an arrow Bx that passes into the first rotor core **204** or the second rotor core **205** are produced between the first rotor core **204** and the second rotor core **205**. Due to this, the rotor **203** functions as the Randell type motor in the magnetic field system and is capable of rotating relative to the stator **202**.

Thus, in the case of the seventh embodiment, the connecting magnet **206** for providing the polarities to the first and second rotor cores **204**, **205** is configured by the integrated connecting magnet **206** in which the magnet main body portion **216**, the interpolar magnet portions **217**, and the back magnet portions **218** are integrated. Thus, the number of components required for the connecting magnet **206** can be suppressed to a small number. Due to this, the number of assembly steps for the rotor **203** can be reduced, and an assembly cost can be suppressed. Further, since the connecting magnet **206** in itself constitutes a single large component, durability against a centrifugal force generated upon a rotation of the rotor becomes high. Due to this, scattering of the interpolar magnet portions **217** in the connecting magnet **206** due to the centrifugal force of the rotor can be made unlikely to occur.

Further, in the rotor **203** of the seventh embodiment, in the case of employing, as the magnet material of the connecting magnet **206**, for example the bonded magnet and the like, the integrated connecting magnet **206** can be formed by insert-forming the bonded magnet into the first rotor core **204** (or the second rotor core **205**). By so doing, since no adhesive layers or mechanical air gaps will be generated between the first rotor core **204** (or the second rotor core **205**) and the connecting magnet **206**, permeance of the motor **201** can be increased, and an effect of torque improvement becomes high.

According to the configuration of the seventh embodiment, advantages as described below can be achieved.

(21) The connecting magnet **206** that causes the first and second rotor cores **204**, **205** to function as the iron cores of the N pole and the S pole is provided between the first rotor core **204** and the second rotor core **205**. The connecting magnet **206** is formed in the shape including the magnet main body portion **216** that fills the gap in the axial direction provided between the first rotor core **204** and the second rotor core **205**, the interpolar magnet portions **217** that fill the gaps in the circumferential direction provided between the hook-shaped poles **209**, **212**, and the back magnet portions **218** that fill the gaps provided at the back surfaces of the respective hook-shaped poles **209**, **212**, while forming them into a single integrated component. Due to this, a structure for preventing leakage of magnetic flux from the gaps between the first rotor core **204** and the second rotor core **205** can be realized with a small number of components. Further, since the number of components of the rotor **203** can be reduced, the assembly steps of the components can be reduced, whereby the assembly cost of the components can be kept low. Further, since the connecting magnet **206** becomes a single component having a relatively large mass, the scattering of the connecting magnet **206** caused by the centrifugal force of the rotor **203** can be made unlikely to occur.

(22) The magnet main body portion **216** is magnetized in the axial direction of the rotor, the interpolar magnet portions **217** are magnetized in the circumferential direction of the rotor, and the back magnet portions **218** are magnetized in the radial direction of the rotor. Thus, since the magnetic moments M1 to M3 of the magnet main body portion **216**, the interpolar magnet portions **217**, and the back magnet portions **218** are magnetized in their optimal directions, N pole and S pole with strong magnetic flux can be generated respectively in the first rotor core **204** and the second rotor core **205**.

(23) In the case of forming the integrated connecting magnet **206** by the sintered magnet or the bonded magnet, since it becomes possible to form the integrated connecting magnet **206** for example by either compression forming or injection forming, a manufacturing method thereof is not limited to one method.

(24) Since the integrated connecting magnet **206** can be formed by the ferrite magnet, the samarium-iron-nitrogen magnet, the samarium-cobalt magnet, the neodymium magnet, the Al—Ni—Co magnet, or the like, the integrated connecting magnet **206** can be manufactured even from such widely-used materials.

(25) Since the rotor cores **204**, **205** and the integrated connecting magnet **206** are assembled firmly by latching of

protrusions and recess patterns of one another, an effect of retaining a state in which the components are positioned becomes prominent.

(26) Since the first and second rotor cores **204**, **205** are assembled firmly with the integrated connecting magnet **206** by a magnetic force thereof, the effect of retaining the state in which the components are positioned becomes more prominent.

(27) For example, in the case of forming the integrated connecting magnet **206** by insert-forming the bonded magnet and the like in the rotor core **204** (**205**), since no adhesive layers or mechanical air gaps will be generated between the rotor core **204** (**205**) and the connecting magnet **206**, the permeance of the motor **201** can be increased, and the effect of torque improvement becomes high.

The seventh embodiment is not limited to the aforementioned configurations, and may be changed to the following embodiment.

As in an integrated connecting magnet (integrated auxiliary magnet) **206** shown in FIG. **41**, magnetized manners of interpolar magnet portions **217** and back magnet portions **218** that function auxiliary relative to a primary magnet main body portion **216** may be of polar anisotropic orientation. More specifically, the so-called magnetization with the polar anisotropic orientation is performed on the interpolar magnet portions **217** and the back magnet portions **218** such that magnetic flux flows while being curved (protruding inwardly in a radial direction) from outer surfaces of the back magnet portions **218** that are of S poles to outer surfaces of the back magnet portions **218** that are of N poles via adjacent interpolar magnet portions **217**. Due to this, since the back magnet portions **218** have magnetic flux with radial components, and the interpolar magnet portions **217** have magnetic flux with circumferential components, the connecting magnet **206** shown in FIG. **41** functions similar to the integrated connecting magnet **206** shown in FIG. **39**. That is, in the integrated connecting magnet **206** shown in FIG. **41** also, rectification of the magnetic flux in the rotor **203** is performed by the interpolar magnet portions **217** and the back magnet portions **218**, and an effect of reducing magnetic flux leakage is exhibited. According to this configuration, the interpolar magnet portions and the back magnet portions can be magnetized to have the components in the respectively optimal directions, and in addition, the magnetization of both portions can collectively be performed from the outer surface sides of the back magnet portions.

As to a method of magnetization of the integrated connecting magnet **206** shown in FIG. **41**, a magnetizing device **220** shown in FIGS. **42**A and **42**B is used. FIG. **42**B shows a first magnetizing device **221** that magnetizes the magnet main body portion **216** of the integrated connecting magnet **206**. The first magnetizing device **221** has magnetizing portions **221***a*, **221***b* with different poles that respectively face front and back surfaces of the disk shaped magnet main body portion **216**, and magnetization along a thickness direction (axial direction) of the magnet main body portion **216** is performed. Further, in FIGS. **42**A and **42**B, a second magnetizing device **222** that magnetizes the interpolar magnet portions **217** and the back magnet portions **218** is shown. The second magnetizing device **222** has five each of magnetizing portions **222***a*, **222***b* with different poles, that is a total of ten, arranged alternately at equal intervals in a circumferential direction. Further, the respective magnetizing portions **222***a*, **222***b* face corresponding outer surfaces of the back magnet portions **218** that are arranged at ten positions in the circumferential direction at equal intervals. Accordingly, the magnetization is collectively performed from the outer surface sides of the back magnet portions **218**, and the magnetization (with the aforementioned polar anisotropic orientation) that curves across the adjacent back magnet portions **218** with the interpolar magnet portion **217** sandwiched therebetween is performed.

Further, in regards to an order of magnetization of the magnet main body portion **216**, the interpolar magnet portions **217**, and the back magnet portions **218**, if the magnetization of the magnet main body portion **216** is performed simultaneously as that of the interpolar magnet portions **217** and the back magnet portions **218**, the number of magnetizing steps can be reduced, and thereby the integrated connecting magnet **216** can be formed in a short period of time. Further, if the magnetization of the magnet main body portion **216** and the magnetization of the interpolar magnet portions **217** and the back magnet portions **218** are performed differently in time, interference of the magnetic flux upon magnetizing the magnet main body portion **216** and the magnetic flux upon magnetizing the interpolar magnet portions **217** and the back magnet portions **218** can be prevented. Especially, if the magnetization on a magnet main body portion **216** side is performed preceding in time, the magnetization of the magnet main body portion **216** side can be expected to be ensured; whereas if the magnetization on interpolar magnet portions **217** and back magnet portions **218** sides is performed preceding in time, the magnetization of the interpolar magnet portions **217** and back magnet portions **218** sides can be expected to be ensured.

As shown in FIG. **43** and FIG. **44**, a rotation shaft **207** may be formed integrally with a first rotor core **204** and a second rotor core **205**. In this case, since a connecting magnet **206** can be of a simple disk without any holes, an increase in magnetic flux that is to be lost at a hole portion can be expected, and an effect of torque improvement becomes high. Further, since a hole processing on the connecting magnet **206** becomes unnecessary, a reduction in a manufacturing cost can also be expected. Moreover, since the rotor cores **204**, **205** will be given a function of the rotation shaft, the rotation shaft **207** as a component becomes unnecessary, and an effect of component number reduction becomes high. In the case of FIG. **43** and FIG. **44**, although the connecting magnet **206** is described as having a simple disk shape, this may be changed to the integrated connecting magnet described in the seventh embodiment and further examples thereof.

The rotor **203** is not limited to a one-layer structure including only one pair of the first rotor core **204** and the second rotor core **205**, and may have a tandem structure as shown in FIG. **45**. The rotor with the tandem structure is configured of a plurality of rotor units **231**, **231**. A rotor unit **231** of the seventh embodiment is identical to the rotor **203** described in the seventh embodiment. Further, in the case with the tandem structure, the rotor units **231**, **231** are arranged upside down with each other in an axial direction such that their N poles (or S poles) make contact with each other. Notably, although in the case of FIG. **45** also, the connecting magnets **206** are described as having a simple disk shape, they may be changed to integrated connecting magnets **206** described in the seventh embodiment. By employing the tandem structure, since larger areas of the N pole and the S pole at the surfaces of each connecting magnet **206** can be provided, an effect of torque improvement is high.

In the case of configuring the rotor **203** in the tandem structure, as shown in FIG. **46**, first rotor cores **204** (or second rotor cores **205**) that made contact with each other at their same poles may be formed integrally. In the case of FIG. **46**, the rotor cores of the N poles are formed integrally. In the case of FIG. **46** also, although the connecting magnets **206** are described as having a simple disk shape, they may be changed to integrated connecting magnets.

The number of the hook-shaped poles **209**, **212** are not limited to the numbers described in the seventh embodiment, and may be changed to other numbers.

The first rotor core **204** may be the S pole, and the second rotor core **205** may be the N pole.

As a material of the integrated connecting magnet **206**, those other than the materials described in the seventh embodiment may suitably be employed.

The shape of the integrated connecting magnet **206** is not limited to the shape described in the seventh embodiment, and may be changed to any shape so long as the magnet main body portion **216**, the interpolar magnet portions **217**, and the back magnet portions **218** are included.

The number of the interpolar magnet portions **217** and the back magnet portions **218** may suitably be changed in accordance with the numbers of the hook-shaped poles **209**, **212**.

The magnetized directions of the magnet main body portion **216**, the interpolar magnet portions **217** and the back magnet portions **218** may be changed to other directions so long as the first and second rotor cores **204**, **205** can be given the desired poles.

Eighth Embodiment

An eighth embodiment of the present invention will be described below in accordance with the drawings. Notably, for convenience of description, same configurations as the first embodiment will be given the same reference signs, and the description thereof will be omitted.

As shown in FIG. **47**A to FIG. **48**, a rotor **311** includes first and the second rotor cores **321**, **322**, a ring magnet **323** as a field magnet (see FIG. **48**), first and second back auxiliary magnets **324**, **325**, and interpolar magnet portions **326**. Notably, arrows in FIG. **47**A to FIG. **48** shown with solid lines respectively indicate magnetized directions (oriented from an S pole to an N pole) of respective magnets **323**, **324**, **325**, **326**.

As shown in FIG. **47**A to FIG. **48**, since the first and second rotor cores **321**, **322**, the ring magnet **323**, the first back auxiliary magnets **324**, and the second back auxiliary magnets **25** of the eighth embodiment correspond to the first and the second rotor cores **21**, **22**, the ring magnet **23**, the first back auxiliary magnets **24**, and the second back auxiliary magnets **25** of the first embodiment, descriptions thereof will be omitted.

In the rotor **311**, first hook-shaped poles **321***b* that are to be the N poles and second hook-shaped poles **322***b* that are to be the S poles are alternately arranged in a circumferential direction, and the number of poles in the rotor **311** is ten (five pole pairs).

The first back auxiliary magnets **324** and the second back auxiliary magnets **325** have their axial lengths set such that they overlap with each other in an axial direction at an axial position in the rotor **311** in which the ring magnet **323** is to be arranged; in other words, such that they extend to the axial position where the ring magnet **323** is arranged from both surfaces of the rotor **311**. In the rotor **311** with such a configuration, it assumes a structure in which the second hook-shaped poles **322***b* having the second back auxiliary magnets **325** arranged therein and the first hook-shaped poles **321***b* are alternately arranged in the circumferential direction at a part in the axial direction where a first core base **321***a* is included. Further, at a part in the axial direction where the ring magnet **323** is included, a structure thereof becomes similar to that of a typical rotor (having permanent magnets with different poles arranged alternately in the circumferential direction) with the first and the second back auxiliary magnets **324**, **325**. Further, at a part in the axial direction where a second core base **322***a* is included, it assumes a structure in which the first hook-shaped poles **321***b* having the first back auxiliary magnets **324** arranged therein and the second hook-shaped poles **322***b* are arranged alternately in the circumferential direction.

As shown in FIGS. **47**A, **47**B, and **49**, the interpolar magnet portions **326** are arranged between the first hook-shaped poles **321***b* and the second hook-shaped poles **322***b* in the circumferential direction. More specifically, the interpolar magnet portions **326** are arranged on only one side of the respective first and the second hook-shaped poles **321***b*, **322***b*. Each of the interpolar magnet portions **326** is fixed to fit between a flat surface formed by a circumferential end surface **321***d* of the first hook-shaped pole **321***b* at a first side (side in a counter-clockwise direction) and a circumferential end surface of the first back auxiliary magnet **324** on the first side, and a flat surface formed by a circumferential end surface **22***c* of the second hook-shaped pole **322***b* on a second side (side in a clockwise direction) and a circumferential end surface of the second back auxiliary magnet **25** on the second side. The interpolar magnet portions **326** are magnetized in the circumferential direction so that their parts facing the corresponding ones of the hook-shaped poles **321***b*, **322***b* have the same polarities therewith (the parts on the first hook-shaped pole **321***b* side are the N poles, and the parts on the second hook-shaped pole **322***b* side are the S poles). A gap K is formed between a radially inner end surface **326***a* of each interpolar magnet portion **326** and outer circumferential surfaces **321***f*, **322***f* of the first and second core bases **321***a*, **322***a*. Notably, a gap is formed between a circumferential end surface **321***c* of each first hook-shaped pole **321***b* on the second side (side in the clockwise direction) and a circumferential end surface **22***d* of each second hook-shaped pole **322***b* on the first side (side in the counter-clockwise direction).

Next, the operation of a motor **301** will be described.

In the rotor **311**, magnetic flux leakage between the hook-shaped poles **321***b*, **322***b* is reduced by the interpolar magnet portions **326**, which are magnetized such that their parts with the same polarities as the corresponding ones of the first and the second hook-shaped poles **321***b*, **322***b* face thereto, arranged between the first and second hook-shaped poles **321***b*, **322***b* in the circumferential direction. The interpolar magnet portions **326** are arranged on only one side of the first and second hook-shaped poles **321***b*, **322***b* (side of the circumferential end surfaces **321***d*, **322***c*), and the number thereof is five, which is half the number of poles in the rotor **311**.

Here, in the aforementioned motor **301** (rotor **311**), for example, compared to a case in which (a total of ten interpolar magnet portions) the interpolar magnet portions **326** are arranged in every interval between the first and second hook-shaped poles **321***b*, **322***b* in the circumferential direction, in a case where none of (zero) interpolar magnet portions is arranged, an output of the motor **301** decreases by about 40%. On the other hand, in a case where the interpolar magnet portions **326** are arranged on the one side of the first and second hook-shaped poles **321***b*, **322***b* as in the rotor **311** of the eighth embodiment, the decrease in the motor output is less than 20% compared to the case of arranging the interpolar magnet portions in every interval in the circumferential direction. That is, compared to the case of simply omitting the interpolar magnet portions **326**, a magnetic balance in the rotor **311** is improved and a cogging torque is reduced by regularly arranging the interpolar magnet portions **326** at a reduced total number, whereby the decrease in the output (decreasing rate) due to the reduction of the interpolar magnet portions **326** can be suppressed. Accordingly, the improvement in the output of the motor **301** can be achieved effectively with less number of the interpolar magnet portions **326** than the number of poles in the rotor **311** while suppressing an increase in the number of components. Further, such a rotor **311** is especially useful in adapting to a low-power motor in which an influence in an output variation caused by the reduction of the interpolar magnet portions **326** is relatively small.

Further, in the case of arranging the interpolar magnet portions **326** in every interval in the circumferential direction, since the same number of the interpolar magnet portions **326** as the number of the poles of the rotor **311** will be required, not only the number of components increase according to the increase in the poles, but also an assembly work therefore becomes burdensome. Contrary to this, by reducing the number of the interpolar magnet portions **326** as in the rotor **311** of the eighth embodiment, the increase in the number of components according to the increase in the poles can be suppressed. That is, assembly workability can be improved, and a manufacturing cost can be reduced.

Next, advantages that are characteristic to the eighth embodiment will be described below.

(28) In the rotor **311** of the eighth embodiment, the interpolar magnet portions **326** that are magnetized to have their parts with the same polarities as the corresponding ones of the hook-shaped poles **321***b*, **322***b* to face thereto are arranged between the first hook-shaped poles **321***b* and the second hook-shaped poles **322***b* in the circumferential direction, regularly (on the one side of the hook-shaped poles **321***b*, **322***b*) at the number (five) less than the number of poles of the rotor **311**. The magnetic flux leakage generated at the respective hook-shaped poles **321***b*, **322***b* is reduced by arranging the interpolar magnet portions **326**, and the magnetic balance in the rotor **311** is improved and the cogging torque thereof is reduced by arranging the interpolar magnet portions **326** regularly. That is, the increase in the number of components is suppressed by arranging the interpolar magnet portions **326** at the appropriate positions, and the improvement in the output of the motor **301** can be achieved effectively with the reduced number of interpolar magnet portions **326**.

Further, by appropriately arranging the reduced number of interpolar magnet portions **326**, the increase in the number of components according to the increase in the poles in the rotor **311** can be suppressed. Due to this, the assembly workability of the rotor **311** can be improved, and the manufacturing cost can be reduced.

(29) The number of the interpolar magnet portions **326** is half the number of poles in the rotor **311**, and the interpolar magnet portions **326** can easily and regularly be arranged between the first and second hook-shaped poles **321***b*, **322***b*.

(30) The first and the second back auxiliary magnet **324**, **325** that are magnetized to have their parts with the same polarities as the poles of the respective hook-shaped poles **321***b*, **322***b* on an outer side in the radial direction are arranged on the back surfaces **321***e*, **322***e* of the first and second hook-shaped poles **321***b*, **322***b*. Due to this, the magnetic flux leakage generated in each of the hook-shaped poles **321***b*, **322***b* and between them and the ring magnet **323** (field magnet) can be reduced, and further contribution to a high output motor **301** can be achieved.

The eighth embodiment may be changed as follows.

In the eighth embodiment, the number and the arranged positions of the interpolar magnet portions **326** are presented by way of example, and may suitably be changed. For example, at least one interpolar magnet portion **326** may be omitted between first hook-shaped poles **321***b* and second hook-shaped poles **322***b* in a circumferential direction. In this case, the interpolar magnet portions **326** are preferably arranged regularly.

Further, although in the eighth embodiment, the rotor **311** having the number of poles of ten (five pole pairs), that is, the rotor **311** having an odd number of pole pairs is used, for example, rotors **331**, **332** having an even number of pole pairs, namely, the rotor **331** as shown in FIG. **50**A having the number of poles of eight (four pole pairs), or the rotor **332** as shown in FIG. **50**B having the number of poles of twelve (six pole pairs), may be used. In each of the rotors **331**, **332**, the second hook-shaped poles **322***b* at which interpolar magnet portions **326** are not arranged at the two sides in the circumferential direction and the second hook-shaped poles **322***b* with the interpolar magnet portions **326** on only one side in the circumferential direction are set to be same numbers (half the number of poles), which are arranged alternately in the circumferential direction. Due to this, the interpolar magnet portions **326** can easily and regularly be arranged relative to each of the rotors **331**, **332**, whereby an increase in the number of components is suppressed, and an improvement in an output of a motor **301** can be achieved effectively with the reduced number of interpolar magnet portions **326**. Notably, an arrangement of the interpolar magnet portions **326** may be a combination of poles with the interpolar magnet portions on one side or both sides in the circumferential direction, and poles without the interpolar magnet portions. Further, such combinations may be adapted to the rotor **311** having the odd number of pole pairs.

In the eighth embodiment, a shape of the interpolar magnet portions **326** is shown by way of example, and the shape may suitably be changed. For example, they may have a shape that completely fits within each gap K.

In the eighth embodiment, its configuration may be changed to a configuration in which the first and second back auxiliary magnets **324**, **325** are omitted.

Although not specifically mentioned in the eighth embodiment, the rotor **311** and the stator **306** may be configured for example by stacking magnetic metal plate materials, or molding magnetic powder materials.

Ninth Embodiment

Herein below, the ninth embodiment of the present invention will be described with reference to FIG. **51** to FIG. **55**.

As shown in FIG. **51**, a stator S is fixed at an inside of a motor case (not shown) of a brushless motor **401**. A stator core **402** of the stator S is formed by stacking a plurality of stator core pieces **402***a* formed of iron plates.

As shown in FIG. **51**, at an inside of the stator core **402**, a rotor R that is inserted into and fixed to a rotation shaft **403** is arranged. The rotation shaft **403** is a non-magnetic metal shaft in the ninth embodiment, and is rotatably supported by a bearing (not shown) provided in the motor case. The rotor R fixed to the rotation shaft **403** is a rotor R with a Randell type structure.

As shown in FIG. **52** to FIG. **54**, the rotor R includes a first rotor core **410**, a second rotor core **420** arranged to face the first rotor core **410**, and a ring magnet **430** arranged between the first rotor core **410** and the second rotor core **420** (see FIG. **53** and FIG. **54**).

As shown in FIG. **54**, the first rotor core **410** includes a first core base **412**, and is fixed to the rotation shaft **403**.

Five first arm portions **413** are formed to protrude in a radial direction at equal intervals at an outer circumferential surface **412***a* of the first core base **412**. A width of each of the first arm portions **413** in a circumferential direction is formed so as to be smaller than an interval with an adjacent first arm portion **413**. An outer circumferential surface **413***a* of each first arm portion **413** is an arc-shaped surface having a center axis line C of the rotation shaft **403** at its center in an axial view. Both side surfaces **413***b* of each first arm portion **413** in the circumferential direction are plan surfaces, and the plan surfaces are formed to intersect with the center axis line C of the rotation shaft **403**.

Further, on the outer circumferential surface **412***a* of the first core base **412**, first fitting recess portions **415** formed in an arc shape in the axial view are concavely formed between the respective first arm portions **413**. Each of the arc-shaped first fitting recess portions **415** has its deepest part positioned at a midpoint in a radial direction of the first arm portions **413** on its both sides, and is formed such that a normal line that passes through the deepest part intersects with the center axis line C of the rotation shaft **403**.

Further, each first fitting recess portion **415** is concavely formed such that its opening width in the circumferential direction becomes smaller than a width between the adjacent first arm portions **413** in the circumferential direction. Accordingly, a stepped surface that is formed by the outer circumferential surface **412***a* of the first core base **412** and the side surface **413***b* of the first arm portion **413** is positioned on the both sides of the opening of the first fitting recess portion **415**.

A first hook-shaped pole **411** that extends toward the second rotor core **420** is formed along an axial direction at a distal end portion of each first arm portion **413** on a second rotor core **420** side.

That is, the first rotor core **410** has the first hook-shaped poles **411** formed toward the second rotor core **420** from the five first arm portions **413** formed on the first core base **412**. Further, each first arm portion **413** forms a base portion that is a part of the corresponding first hook-shaped pole **411**.

A width of an outer surface **411***a* of each first hook-shaped pole **411** in the circumferential direction is same as the width of the outer circumferential surface **413***a* of the first arm portion **413** in the circumferential direction. Further, the outer surfaces **411***a* are level with the outer circumferential surfaces **413***a*, and are formed on the same arc-shaped surface therewith.

Further, an inner surface **411***b* of each first hook-shaped pole **411** is expanded to an inside of the first core base **412** than the first arm portions **413**. The inner surface **411***b* has different shapes divided with an extended line of an intersecting line as a borderline, obtained by intersecting the outer circumferential surface **412***a* of the first core base **412** and the side surfaces **413***b* of the first arm portion **413**.

More specifically, a part of the inner surface **411***b* on a side separated from the center axis line C with respect to the aforementioned extended line as a borderline are formed to be flush with the side surfaces **413***b* of the first arm portion **413**. On the other hand, a part closer to the center axis line C with respect to the aforementioned extended line as the borderline is formed to be an arc-shaped surface having an arc shape toward the center axis line C in the axial view. Accordingly, the inner surface **411***b* of each first hook-shaped pole **411** is formed in a U-shape.

The second rotor core **420** is configured of the same shape and the same material as of the first rotor core **410**, and as shown in FIG. **54**, includes a second core base **422**, and is fixed to the rotation shaft **403**.

Five second arm portions **423** are formed to protrude in the radial direction at equal intervals on an outer circumferential surface **422***a* of the second core base **422**. A width of each of the second arm portions **423** in the circumferential direction is formed so as to be smaller than an interval with an adjacent second arm portion **423**. An outer circumferential surface **423***a* of each second arm portion **423** is an arc-shaped surface having the center axis line C of the rotation shaft **403** at its center in the axial view. Both side surfaces **423***b* of each second arm portion **423** in the circumferential direction are plan surfaces, and the plan surfaces are formed to intersect with the center axis line C of the rotation shaft **403**.

Further, on the outer circumferential surface **422***a* of the second core base **422**, second fitting recess portions **425** formed in an arc shape in the axial view are concavely formed between the second arm portions **423**. Each of the arc-shaped second fitting recess portions **425** has its deepest part positioned at a midpoint in the radial direction of the second arm portions **423** on its both sides, and is formed such that a normal line that passes through the deepest part intersects with the center axis line C of the rotation shaft **403**.

Further, each second fitting recess portion **425** is concavely formed such that its opening width in the circumferential direction becomes smaller than a width between the adjacent second arm portions **423** in the circumferential direction. Accordingly, a stepped surface that is formed by the outer circumferential surface **422***a* of the second core base **422** and the side surface **423***b* of the second arm portion **423** is positioned on the both sides of the opening of the second fitting recess portion **425**.

A second hook-shaped pole **421** that extends along the axial direction toward the first rotor core **410** is formed at a distal end portion of each second arm portion **423** on a first rotor core **410** side.

That is, the second rotor core **420** has the second hook-shaped poles **421** formed toward the first rotor core **410** from the five second arm portions **423** formed on the second core base **422**. Further, each second arm portion **423** forms a base portion that is a part of the corresponding second hook-shaped pole **421**.

A width of an outer surface **421***a* of each second hook-shaped pole **421** in the circumferential direction is same as the width of the outer circumferential surface **423***a* of the second arm portion **423** in the circumferential direction. Further, the outer surfaces **421***a* are level with the outer circumferential surfaces **423***a*, and are formed on the same arc-shaped surface therewith.

Further, an inner surface **421***b* of each second hook-shaped pole **421** is expanded to an inside of the second core base **422** than the second arm portions **423**. The inner surface **421***b* has different shapes divided with an extended line of an intersecting line as a borderline obtained by intersecting the outer circumferential surface **422***a* of the second core base **422** and the side surfaces **423***b* of the second arm portion **423** intersect.

More specifically, a part of the inner surface **421***b* on a side separated from the center axis line C with respect to the aforementioned extended line as the borderline are formed to flush with the side surfaces **423***b* of the second arm portion **423**. On the other hand, a part closer to the center axis line C side with the aforementioned extended line as the borderline is formed to be an arc-shaped surface having an arc shape toward the center axis line C in the axial view. Accordingly, the inner surface **421***b* of each second hook-shaped pole **421** is formed in a U-shape.

First rectifying magnets **418** are arranged so as to face the inner surfaces **411***b* of the first hook-shaped poles **411**, and second rectifying magnets **428** of the same shape and the same material as the first rectifying magnets **418** are arranged so as to face the inner surfaces **421***b* of the respective second hook-shaped poles **421**.

Each first rectifying magnet **418** has a cross-sectional shape in the radial direction of a U-shape, and an inner surface **418***b* thereof has the same shape as the inner surface **411***b* of the corresponding first hook-shaped pole **411** to make tight contact therewith. An outer surface **418***a* of each first rectifying magnet **418** has the same shape as the recessed surface of the corresponding second fitting recess portion **425** formed on the outer circumferential surface **422***a* of the second core base **422** to make tight contact therewith.

Further, an outer surface of each first rectifying magnet **418** in the radial direction (outer surface of the first rectifying magnet **418** in a direction parallel to the radial direction of the rotor R) is formed in an arc shape that is level with the outer surfaces **411***a* of the first hook-shaped poles **411**.

On the other hand, each second rectifying magnet **428** has a cross-sectional shape of a U-shape in the radial direction, and an inner surface **428***b* thereof has the same shape as the inner surface **421***b* of the corresponding second hook-shaped pole **421** to make tight contact therewith. An outer surface **428***a* of each second rectifying magnet **428** has the same shape as the recessed surface of the corresponding first fitting recess portion **415** formed on the outer circumferential surface **412***a* of the first core base **412** to make tight contact therewith.

Further, an outer surface of each second rectifying magnet **428** in the radial direction (outer surface of the second rectifying magnet **428** in a direction parallel to the radial direction of the rotor R) is formed in an arc shape that is level with the outer surfaces **421***a* of the second hook-shaped poles **421**.

As shown in FIG. **54**, each first rectifying magnet **418** includes a pair of first extended portions **419** that extends from both end portions of the first rectifying magnet **418** on the first rotor core **410** side so as to make tight contact with the stepped surfaces formed by the outer circumferential surface **412***a* of the first core base **412** and the side surfaces **413***b* of the corresponding first arm portion **413**.

Outer surfaces **419***a* of both first extended portions **419** in the radial direction (outer surfaces of the first extended portions **419** in a direction parallel to the radial direction of the rotor R) are formed in an arc-shape to be respectively level with the outer circumferential surface **413***a* of the first arm portion **413**. Further, inner surfaces **419***b* of the both first extended portions **419** in the radial direction are formed in an arc shape so as to be level with the outer circumferential surface **412***a* of the first core base **412**.

Further, both side surfaces **419***c* of the both first extended portions **419** in the circumferential direction (outer surfaces of the first extended portions **419** in a direction along the circumferential direction of the rotor) are formed respectively in a shape to make tight contact with the side surface **413***b* of the corresponding first arm portion **413** and in a shape to make tight contact with the outer surface **428***a* of the corresponding second rectifying magnet **428** that fits with the recessed surface of the corresponding first fitting recess portion **415**.

Yet further, distal end surfaces of the both first extended portions **419** are formed as plan surfaces, that become level with a surface **422***c* of the first core base **412** on the opposite side from the second rotor core **420** side (see FIG. **53**) when the first rectifying magnets **418** are arranged to face the inner surfaces **411***b* of the first hook-shaped poles **411**.

As shown in FIG. **54**, each second rectifying magnet **428** includes a pair of second extended portions **429** that extends from both end portions of the second rectifying magnet **428** on the second rotor core **420** side so as to make tight contact with the stepped surfaces formed by the outer circumferential surface **422***a* of the second core base **422** and the side surfaces **423***b* of the corresponding second arm portion **423**.

Outer surfaces **429***a* of both second extended portions **429** in the radial direction (outer surfaces of the second extended portions **429** in a direction parallel to the radial direction of the rotor R) are formed in an arc-shape to be respectively level with the outer circumferential surface **423***a* of the second arm portion **423**. Further, inner surfaces **429***b* of the both second extended portions **429** in the radial direction are formed in an arc shape so as to be level with the outer circumferential surface **422***a* of the second core base **422**.

Further, both side surfaces **429***c* of the both second extended portions **429** in the circumferential direction (outer surfaces of the second extended portions **429** in a direction along the circumferential direction of the rotor) are formed respectively in a shape to make tight contact with the side surface **423***b* of the corresponding second arm portion **423** and in a shape to make tight contact with the outer surface **418***a* of the corresponding first rectifying magnet **418** that fits with the recessed surface of the corresponding second fitting recess portion **425**.

Yet further, distal end surfaces of the both second extended portions **429** are formed as plan surfaces, that become level with a surface **412***c* of the second core base **422** on the opposite side from the first rotor core **410** side (see FIG. **53**) when the second rectifying magnets **428** are arranged to face the inner surfaces **421***b* of the second hook-shaped poles **421**.

Further, in a state in which the first rectifying magnets **418** are arranged to surround the first hook-shaped poles **411** and the second rectifying magnets **428** are arranged to surround the second hook-shaped poles **421**, the first rotor core **410** and the second rotor core **420** overlap such that the first hook-shaped poles **411** and the second hook-shaped poles **421** are arranged alternately.

When the first hook-shaped poles **411** and the second hook-shaped poles **421** are arranged alternately in the circumferential direction, the side surfaces **419***c* of the first rectifying magnets **418** make tight contact with the outer surfaces **428***a* of the second rectifying magnets **428**. Similarly, the side surfaces **429***c* of the second rectifying magnets **428** make tight contact with the outer surfaces **418***a* of the first rectifying magnets **418**.

As shown in FIG. **55**, the first rectifying magnets **418** including the first extended portions **419** are magnetized toward a first hook-shaped pole **411** side (toward a first arm portion **413** side in the first extended portions **419**) so as to be vertical to the inner surfaces **418***b* (side surfaces **419***c* in the first extended portions **419**) of the first rectifying magnets **418**. Further, the first rectifying magnets **418** are magnetized such that the first hook-shaped pole **411** side (first arm portion **413** side in the first extended portions **419**) becomes the N pole, and a side opposite from the first hook-shaped pole **411** side (side opposite from the first arm portion **413** side in the first extended portions **419**) is the S pole.

Further, as shown in FIG. **55**, the second rectifying magnets **428** including the second extended portions **429** are magnetized toward a side opposite from a second hook-shaped pole **421** side (toward an opposite side from a second arm portion **423** side in the second extended portions **429**) so as to be vertical to the outer surfaces **428***a* of the second rectifying magnets **428** (side surfaces **429***c* in the second extended portions **429**). Further, the second rectifying magnets **428** are magnetized such that a side opposite from the second hook-shaped pole **421** side (side opposite from the second arm portion **423** side in the second extended portions **429**) is the N pole, and the second hook-shaped pole **421** side (second arm portion **423** side in the second extended portions **429**) is the S pole.

Further, upon overlapping the first rotor core **410** and the second rotor core **420** so that the first hook-shaped poles **411** and the second hook-shaped poles **421** are arranged alternately in the circumferential direction, the ring magnet **430** is arranged between the first rotor core **410** and the second rotor core **420**.

The ring magnet **430** is sandwiched and fixed by the first rotor core **410** and the second rotor core **420**. Further, both side surfaces **430***a*, **430***b* of the ring magnet **430** in the axial direction respectively make contact with the corresponding surfaces **412***b*, **422***b* in a face-to-face relation therewith, of the first and second core bases **412**, **422**. The ring magnet **430** includes a through hole **430***c* at its center, through which the rotation shaft **403** is inserted. An outer circumferential surface **430***d* of the ring magnet **430** contacts the outer circumferential surfaces of the first rectifying magnets **418** and the second rectifying magnets **428**, that is, with parts closest to the center axis line C, of the first rectifying magnets **418** and the second rectifying magnets **428**.

The ring magnet **430** is magnetized in the axial direction such that the first core base **412** side is the N pole, and the second core base **422** side is the S pole. Accordingly, by the ring magnet **430**, the respective first hook-shaped poles **411** of the first rotor core **410** function as the N pole (first pole) and the respective second hook-shaped poles **421** of the second rotor core **420** function as the S pole (second pole).

Next, the operation of the rotor R configured as above will be described.

The U-shaped first rectifying magnets **418** are arranged to respectively surround the respective first hook-shaped poles **411** of the first rotor core **410**. At this occasion, since a single first rectifying magnet **418** is mounted on each first hook-shaped pole **411**. Due to small number of components, a work to mount the first rectifying magnets **418** to the first hook-shaped poles **411** can be performed within a short period of time.

Further, the U-shaped second rectifying magnets **428** are arranged to respectively surround the respective second hook-shaped poles **421** of the second rotor core **420**. At this occasion, similarly, since a single second rectifying magnet **428** is mounted on each second hook-shaped pole **421**. Due to small number of components, a work to mount the second rectifying magnets **428** to the second hook-shaped poles **421** can be performed within a short period of time.

Next, the first rotor core **410** and the second rotor core **420** are combined to overlap so that the first hook-shaped poles **411** and the second hook-shaped poles **421** are arranged alternately in the circumferential direction. In combining as above, the ring magnet **430** is arranged between the first rotor core **410** and the second rotor core **420** to be sandwiched therebetween.

The rotor R is formed by fixing the first rotor core **410** and the second rotor core **420** that sandwich the ring magnet **430** to the rotation shaft **403**.

Next, advantages of the ninth embodiment as configured above will be described below.

(31) According to the ninth embodiment, since first and second rectifying magnet **418**, **428** as a single component is respectively mounted to each of the first and second hook-shaped poles **411**, **421**, the number of components can be made small. Due to this, the work to mount the first and second rectifying magnets **418**, **428** to the respective first and second hook-shaped poles **411**, **421** can be performed within a short period of time. As a result, cost reduction of the rotor R is achieved, and a low cost for the motor **401** can be realized.

(32) According to the ninth embodiment, the inner surfaces **411***b* of the first hook-shaped poles **411** are surrounded by the inner surfaces **418***b* of the first rectifying magnets **418** in a tight contact manner, and the inner surfaces **421***b* of the second hook-shaped poles **421** are surrounded by the inner surfaces **428***b* of the second rectifying magnets **428** in a tight contact manner. Thus, magnetic flux of the first and second rectifying magnets **418**, **428** is effectively used, and an increase of an output of the motor can be achieved.

(33) According to the ninth embodiment, the first rectifying magnets **418** are magnetized to be the N poles similar to the first hook-shaped poles **411** so that a magnetized orientation of the first rectifying magnets **418** becomes vertical to the inner surfaces **411***b* of the first hook-shaped poles **411**. Further, the second rectifying magnets **428** are magnetized to be the S poles similar to the second hook-shaped poles **421** so that a magnetized orientation of the second rectifying magnets **428** becomes vertical to the inner surfaces **421***b* of the second hook-shaped poles **421**. Accordingly, rectification of magnetic paths between the first hook-shaped poles **411** and the second hook-shaped poles **421** is performed more efficiently, and a high output of the motor can be achieved.

The ninth embodiment may be implemented by changing it as follows.

Although in the ninth embodiment, five each of the first and second hook-shaped poles **411**, **421** is formed, the present invention is not limited hereto, and may be implemented with the numbers thereof suitably changed.

Although in the ninth embodiment, the inner surfaces **411***b*, **421***b* of the first and second hook-shaped poles **411**, **421** are formed in a U-shape, the inner surfaces **411***b*, **421***b* may be formed in a C-shape. In this case, the inner surfaces of the rectifying magnets need to be formed into a C-shape correspondingly.

The invention claimed is:

1. A rotor comprising:

a first rotor core including a disk-shaped first core base and a plurality of first hook-shaped magnetic poles arranged at equal intervals on a peripheral portion of the first core base, wherein each of the first hook-shaped magnetic poles protrudes outward in a radial direction of the rotor and includes a first extended portion that extends along an axial direction of the rotor;

a second rotor core including a disk-shaped second core base and a plurality of second hook-shaped magnetic poles arranged at equal intervals on a peripheral portion of the second core base, wherein each of the second hook-shaped magnetic poles protrudes outward in the radial direction and includes a second extended portion that extends along the axial direction, and the first and second hook-shaped magnetic poles are alternately arranged along a circumferential direction of the rotor so that the first and second core bases are opposed in the axial direction;

a field magnet arranged between the first and second core bases in the axial direction, wherein the field magnet is magnetized along the axial direction so that the first hook-shaped poles function as first poles and the second hook-shaped poles function as second poles; and

an auxiliary magnet includes at least two or more interpolar magnet portions that are integrally formed, wherein each of the interpolar magnet portions is arranged in a void between the first hook-shaped poles and the second hook-shaped poles and magnetized in the circumferential direction, wherein

the auxiliary magnet includes back magnet portions arranged on back surfaces of the first and second hook-shaped poles, wherein the back magnet portions are magnetized so that an outer part in the radial direction facing the corresponding back surface has the same polarity as the corresponding hook-shaped pole,

each of the interpolar magnet portions extends outward in the radial direction from the back magnet portion and is magnetized so as to have same polarity as the first and second hook-shaped poles that are adjacent to each other,

the auxiliary magnet includes the back magnet portion and the interpolar, magnet portions that are integrally formed, and the auxiliary magnet contacts the corresponding hook-shaped pole in the radial direction and the circumferential direction, and

the auxiliary magnet is magnetized so as to have the same magnetized direction as the corresponding hook-shaped poles magnetized by the field magnet.

2. The rotor according to claim **1**, wherein

the first and second core bases include outer surfaces facing opposite directions,

the auxiliary magnet includes an axial direction covering magnet portion formed integrally with the interpolar magnet portions to cover the outer surface of one of the first and second core bases; and

the axial direction covering magnet portion is magnetized along the axial direction.

3. The rotor according to claim **1**, wherein

the auxiliary magnet includes a connecting portion located at a distal side of the extended portion in an extending direction and connecting the interpolar magnet portions, and

the auxiliary magnet is formed integrally in advance by connecting the interpolar magnet portions with the connecting portion.

4. The rotor according to claim **1**, wherein the interpolar magnet portions are arranged in all voids between the first and second hook-shaped poles.

5. The rotor according to claim **1**, wherein

the at least two or more interpolar magnet portions are arranged to sandwich each of the first and second hook-shaped poles in the circumferential direction, and

the auxiliary magnet undergoes two-color molding to integrally mold the interpolar magnet portions.

6. The rotor according to claim **1**, wherein

the auxiliary magnet is divided in the circumferential direction into a plurality of circumferentially divided portions that are arranged consecutively and adjacently in the circumferential direction, and

each of the circumferentially divided portions includes the back magnet portion and the interpolar magnet portions.

7. The rotor according to claim **1**, wherein

the auxiliary magnet is divided in the axial direction into a plurality of axially divided portions that are arranged consecutively and adjacently in the axial direction; and

each of the circumferentially divided portions includes the back magnet portion and the interpolar magnet portions.

8. The rotor according to claim **1**, wherein the auxiliary magnet is formed integrally to be annular and includes an anisotropic magnet portion and a different property portion having a magnetic property that differs from the anisotropic magnet portions.

9. The rotor according to claim **1**, wherein

the auxiliary magnet includes a magnet main body portion, which is arranged in a gap in the axial direction between the first rotor core and the second rotor core, and a back magnet portion arranged in a gap at back surface sides of the first and second hook-shaped poles, and

the auxiliary magnet includes the magnet main body portion, the back magnet portion, and the interpolar magnet portions, which are integrally formed.

10. The rotor according to claim **9**, wherein

the magnet main body portion is magnetized along the axial direction,

the interpolar magnet portions are magnetized along the circumferential direction, and

the back magnet portions are magnetized along the radial direction.

11. The rotor according to claim **9**, wherein the auxiliary magnet has a polar anisotropic orientation of which magnetic flux flows in a curved manner from one of the back magnet portions via the interpolar magnet portion adjacent to the back magnet portion toward the other one of the back magnet portion that has a different pole.

12. The rotor according to claim **1**, wherein

each of the interpolar magnet portions includes a part facing one of the first and second hook-shaped poles; and the part is magnetized to have the same polarity with the corresponding hook-shaped pole, and

the interpolar magnet portions, the number of which is less than the total number of poles of the first and second hook-shaped poles, are arranged regularly.

13. The rotor according to claim **1**, wherein

the auxiliary magnet further includes back magnet portions arranged in gaps at back surface sides of the first and second hook-shaped magnetic poles and

the auxiliary magnet including the back magnet portions and the interpolar magnet portions are formed integrally to be annular.

14. The rotor according to claim **13**, wherein

the interpolar magnet portions are magnetized along the circumferential direction and

the back magnet portions are magnetized along the radial direction.

15. The rotor according to claim **13**, wherein the auxiliary magnet has a polar anisotropic orientation of which magnetic flux flows in a curved manner from one of the back magnet portions via the interpolar magnet portion adjacent to the back magnet portion toward the other one of the back magnet portion that has a different pole.

16. The rotor according to claim **1**, further comprising:

a plurality of first rectifying magnets each surrounds an entire inner surface of the first hook-shaped magnetic pole, wherein each of the first rectifying magnets is formed by a single member; and

a plurality of second rectifying magnets each surrounds an entire inner surface of the second hook-shaped magnetic pole, wherein each of the second rectifying magnets is formed by a single member.

17. A motor comprising the rotor according to claim **1**.

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